Older Drivers' Requirements for Navigation and Route Guidance Information

by

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Abstract

This thesis examines older drivers and navigation. Over more recent times the proportion of older people in the UK population has risen. This effect is carrying over into the driving population. Due to changing demographics, increased longevity and the increased universality of driving there will be many more older drivers than before. Older drivers find the navigation task of finding their way on unfamiliar routes very demanding due to declines in sensory and cognitive abilities. New technology such as route guidance systems could aid the older driver in this task, by reducing uncertainty when meeting decision points on the road network. However such systems can also cause distraction. This has led to concern over the safety implications of the implementation of route guidance systems into cars. If route guidance systems are to be designed safely then the characteristics and needs of the driver have to be identified. The aim of this thesis was to provide human factors knowledge in this area so that route guidance systems can be designed to meet the needs of older drivers.

The research presented in this thesis was based around two studies. The main approach of the first study was a field trial aimed at establishing older drivers' real time information needs and strategies for navigation on unfamiliar routes, along with a comparison to younger drivers. The results were used to develop a set of recommendations for the content and timing of information required by a route guidance system in order to meet the needs of the older driver.

The aim of the second study was to identify the most appropriate method of presenting route guidance information for older drivers e.g. visual presentation, auditory presentation. This study was a computer based experiment carried out in a laboratory, and again comparisons were made with younger drivers.

The results from both studies were used to develop detailed recommendations for the content, timing and presentation of route guidance information suitable for older drivers. A commercially available route guidance system was evaluated against these recommendations.

Keywords: *Older Drivers, Navigation, Route Guidance systems, Information Content, Information Timing, Information Presentation*

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

1.1 Chapter Summary

This chapter introduces the research issues covered in this thesis. It introduces route guidance technology and concerns about this technology and its compatibility with a rising older driver population. The need for a user-centred approach for the design of such technology is also discussed. The aims and objectives of this thesis are described, and the thesis outline presented.

1.2 General Introduction

In-vehicle route guidance systems are one of many recent technological innovations, collectively termed 'road transport informatics' (RTI). Their introduction into the car is intended to assist the driver in the driving task (Burns 1997). Route guidance systems provide the driver with real-time instructions, allowing the driver to proceed along a chosen route (Ashby & Parkes 1993). This can aid the driver in locating unknown destinations and maintaining efficient routes (Burnett and Joyner 1997; Srinivasan & Jovanis 1997), in turn reducing travel time, distance driven, petrol costs (Burns 1997; Dingus & Hulse 1993) and congestion (Konstantinos et al 2000). It is also suggested that by reducing decision making and stress, more attention would be available for the primary tasks of driving (e.g. car control, obstacle avoidance, speed), and thus safety would be improved (Warnes et al 1993; Dingus & Hulse 1993).

The focus of much RTI research has been on technical issues rather than on safety and user acceptance (Wochinger & Boehm-Davis 1997). This has led to concern from human factors practitioners over the safety implications of the implementation of route guidance systems into cars, especially for older drivers (Burns 1997; Federal Highway Administration 1995). Older drivers are more susceptible to cognitive overload and distraction due to declines in information processing abilities. There has also been an increase in the older driver population over recent times, a trend which is set to increase dramatically over the next few decades (Automobile Association 1997).

Ironically older drivers could benefit from route guidance systems even more than other driving populations (Wochinger & Boehm-Davis 1997). Age related declines in spatial ability suggest that older drivers may have diminished navigational skills, therefore increasing the likelihood of getting lost (Federal Highway Administration 1995). Sixsmith (1990) identified navigation in an unfamiliar area as one of the three main problem areas for older drivers. Difficulties in navigation can deter older drivers from travelling in unfamiliar areas, and thus reduce mobility (Burns 1997; AA 1988). Warnes et al (1993) suggest that route finding decisions at junctions contribute to the difficulties of older drivers. Indeed navigation errors by older drivers have been shown to have serious consequences as highlighted by the following newspaper headlines.

"Pensioner's 10-mile drive on M25...the wrong way." (Daily Mail 1997)

"Wrong way pensioner killed in pile-up on the M11" (The Times 1996)

In both of these cases the driver had made an error at a junction and proceeded to travel the exit slip road to the motorway. These are extreme cases, but do demonstrate that navigation itself has safety implications. Thus we have a situation of a system, which could potentially aid older drivers, but needs careful design considerations so it does not itself threaten safety compromising the very reason it was put there.

If route guidance systems are to be designed safely, the characteristics and needs of the driver have to be identified (Burns 1997). The current technology led approach of such systems is not acceptable. Human factors considerations for a route guidance system include what information the driver needs, when it is needed, and how to present this information to the driver. A review of the literature revealed very little is known about the information needs of drivers as they travel a route, and virtually nothing is known about older drivers in these circumstances. Even less is known about the timing of information. Most research into route guidance systems has concentrated on modality of the presentation (e.g. speech, graphical displays).

However this is by no means conclusive and older drivers have been neglected in this research.

The focus of this thesis is the human factors design of route guidance systems in relation to older drivers. To help identify specific differences comparisons were also made with younger drivers. It is often stated that an older person's requirements can induce benefits for younger drivers (e.g. Pauzie & Lettisserand 1992; Nicole 1995). However cohort differences alone e.g. life experience, knowledge across ages, make this assumption unreasonable (Burns 1997).

1.3 Design Issues

In order to successfully incorporate new route guidance technology into the car, it is important to understand the interaction of the driver with components which make up the driving system (see figure 1.1). Only by taking a systems approach will useable and safe RTI systems be designed and the effect on primary safety (accident prevention) be positive (Galer 1984).

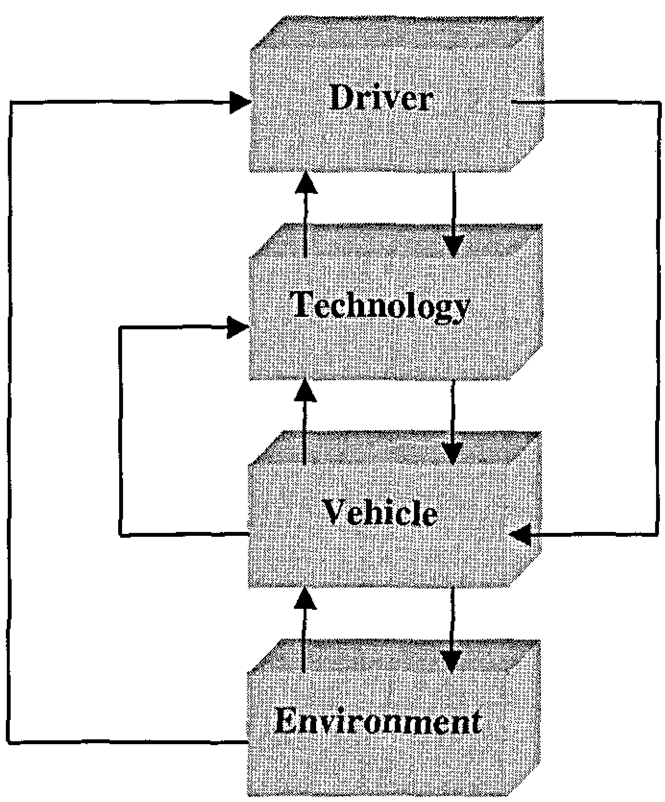


Figure 1.1: Interaction of the components making up the driving system (adapted from Rumar 1993)

An understanding of these elements will help identify how they interact with one another and so aid new components being brought into the system.

The Driver – the driver is central to the system and its interactions, as transport has been traditionally seen as a safe and efficient movement of people, goods and services. Transportation has arisen to fulfil the needs of people and so safe, efficient passage relies on the interaction of the driver with other elements of the system. Figure 1.2 gives an example of how drivers can be categorised:

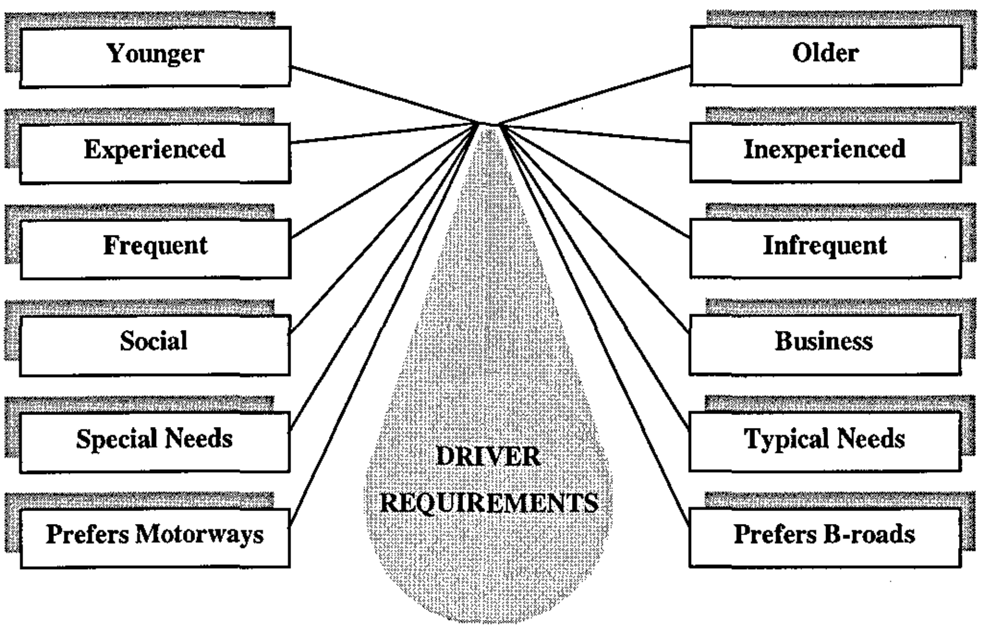


Figure 1.2: Example of how drivers can be categorised (adapted from Ashby & Parkes 1993)

Taking these categorisations of drivers it can be seen that "Older, infrequent, social, B-road preferring drivers will have a wholly different set of requirements to a younger, experience, frequent business driver with special needs" (Ashby & Parkes 1993).

The Vehicle – the vehicle is required to be of optimum specification in order to allow the driver safe control. The driver in this manner has full operational control and the primary task is safe operation through standard controls (e.g. brakes, steering, gears) and so we have the *driver-vehicle* interaction.

The Environment – the environment through which we travel consists of many elements, including landmarks, road networks, and infrastructure developed specifically for transportation purposes. It is from this environment that the driver receives information in order to maintain control of the vehicle e.g. following the correct line along the road (tracking), judging speed, avoiding obstacles; to navigate e.g. using signs, landmarks; and the compliance with highway safety rules e.g. traffic lights. The environment presents an abundance of information to the driver for which s/he must select the most relevant, and make decisions based on it, hence the *driver-environment* interaction. There is also an interaction between the road and the vehicle as well maintained and designed roads allow for optimal control of the car as it passes along it, hence the *vehicle-environment* interaction.

The Technology – in more recent times many different types of technologies have been finding their way into the vehicle. Galer Flyte (1995) categorises these technologies into three distinct groups:-

- Systems that directly impinge on the driving task
- Systems that provide information relevant to components of the driving environment, the vehicle or the driver
- Systems that are unrelated to driving

Systems that directly impinge on the driving task include collision avoidance devices, lane keeping devices, gap warning devices, all of which have a direct impact on the tasks that the driver performs. Systems that provide information relevant to the components of the driving environment, the vehicle and the driver, include monitoring systems which provide information on weather e.g. snow, fog, ice, traffic congestion warnings and route guidance information. These devices provide the driver with information relevant to the driving task, which s/he can use to make decisions, but are not an integral part of the driving task (Galer Flyte 1995). Systems unrelated to the driving task include mobile phones and mobile data terminals, which are unrelated to the primary task of driving.

So it can be seen that the route guidance system falls into the second category. Fundamental to the interaction between the driver and the route guidance system is the development of the interface between the two. This is by means an easy task. All the drivers' needs, abilities, and limitations have to be taken into consideration. Also the technology needs to interact with the environment and the vehicle taking into account the drivers interaction with the environment and the vehicle.

Even though a route guidance system can be seen as not impinging directly on the driving task, poor design may have an indirect effect. For example, if there is a poor match between a signpost in the environment and an instruction on the route guidance system, this may confuse the driver, potentially causing indecision and threatening safety. Also if the interaction between the route guidance system and the driver is poorly designed, it may lead to distraction, again threatening safe car control.

The basis of this research is the provision of information for the safe design of the Human-Machine Interface for a route guidance system. In particular it will take account of the needs of older drivers. Ideally the user interface of such a system should present the driver with concepts consistent with the driver's mental model of that phenomenon in the real world, and so relates to human computer interaction (Mark 1993). Fundamental to the human-computer interaction is the development of the interface.

Lansdale and Omerod (1995) define the term interface as 'the collection of objects, tools languages and displays which lies between people and the machines they intend to use.' The one common property is that they are media through which information is communicated (Lansdale & Omerod 1995). Research has shown that fancy features matter little if they are inaccessible through poor human-computer interaction (Hartson 1985), where as good design has been shown to make a substantial difference in learning time, error rates and user satisfaction (Schneiderman 1992). Sutcliffe (1995) cites three main reasons why good interface design is vital:-

- People often by a product because they like the appearance – what they try out and see is the interface.

- As systems improve and people become aware of good and bad designs they become less tolerant of bad interfaces.
- Poor interfaces can lead to inefficiency or even system failure. This can mean costs in terms of time and money, or in the case of a critical system (such as route guidance systems), it could cost lives.

Despite the commercial appeal of the first two reasons, the third is of most importance in this research, due to the safety critical nature of the driving task.

1.4 Research Aims

The main aim of this research is to provide human factors information so that route-guidance interfaces can be designed to meet the needs of older drivers.

The specific objectives are as follows.

1) Investigate drivers strategies for real time navigation in an unfamiliar area identifying the content of navigational information used, the timing of this information, and differences between older and younger drivers.

2) Identify the suitability of the navigational information content and timing, for inclusion of information to be provided by a route guidance system aimed at older drivers.

3) Investigate the most suitable presentation modality for the chosen route guidance information, identifying differences between older and younger drivers.

4) Produce a set of recommendations for the design of a route guidance interface suitable for the older driver.

5) Evaluate a current commercially available route guidance system against the recommendations, highlighting their current status in meeting the needs of older drivers.

1.5 Outline of the Thesis

The thesis is in two parts. The first part deals with the real-time navigational needs of the driver in terms of the content and timing of information relevant to a route guidance system, highlighting the specific needs of older drivers. The second part of the thesis determines the most appropriate presentation method of this information for older drivers.

Chapter 2 introduces the older driver, the navigation process and new route guidance technology. The first part of the chapter covers older driver issues including declines in physical, sensory and cognitive abilities and evidence of the effects these have on the driving task. The second part of the chapter tackles the complexities of the navigation process. The theories behind navigation in an unfamiliar area are discussed to aid an understanding of this process. Finally route guidance systems and its capabilities are introduced, highlighting their potential for helping older drivers.

Chapter 3 reviews the human factors issues concerning route guidance systems. This chapter specifically focuses on driver information needs and the timing of information. Research in both of these areas is reviewed. The findings of the research are discussed in terms of its applicability to route guidance systems, and gaps in current research highlighted. The methodologies and categorisation schemes for navigational information are also critiqued.

Chapter 4 provides the rationale for the first study. The review of literature in chapter 3 revealed very little was known about driver navigational information needs, the timing of this information, and any age concerns. A field trial is therefore proposed to remedy this situation, identifying real-time information needs, and differences between younger and older drivers, through the use of 'question asking protocols'. Also two conditions are proposed, namely seeing a map prior to driving and driving 'blind' (i.e having no map prior to driving). This was applied due to differing methodologies of previous research to identify any differences in information content between the two situations. The remainder of the chapters describes the methodology for running the field trial, including procedures, measures and the categorisation scheme employed for data analysis.

Chapter 5 presents the results of the field trial. The first part of the chapter presents the general results including amount of information requested by drivers, route times, errors and a high level categorisation of information content. Analyses, look at both age and gender differences, and also differences in seeing a map prior to driving a route, compared to not seeing a map prior to driving a route. The second part of the chapter is detailed analysis of the content and timing of the information requested by drivers, again looking at age and gender differences.

Chapter 6 discusses the results of the field trial. The first part of the chapter discusses the general results, and compares this to previous literature, highlighting the reason behind any age, gender or condition differences. The second part of this chapter discusses the detailed analysis of the content and timing of information requested by drivers, and the reason behind any age and gender differences. The information content is looked at in terms of the way in which it was used, the timing of when it was used and the purpose it served, comparing this to relevant previous research. The suitability of the information for a route guidance system is also discussed. The last part of the chapter summarises all of the discussions and proposes model for how drivers navigate and recommendations for the content and timing of information in a route guidance system.

Chapter 7 firstly introduces the human factors considerations for the modality of the presentation of route guidance information. Research in this area is then reviewed and critiqued, highlighting preferred modalities and age considerations.

Chapter 8 proposes the rationale for the second study in this thesis. Literature in chapter 7 revealed gaps in existing knowledge for comparison of speech only modalities with a combination of speech and visual modalities, and their effects on older drivers. The experiment set up included a computer-based tracking task (to model primary task of driving i.e. car control) and a navigation task, to investigate the safety and efficiency of different presentation modalities. Route guidance information was presented to the driver concurrently with the tasks, either visually, via speech, or a combination of the two. The content and timing of this information was based on the recommendations in chapter 6. Methods and procedures are all presented within this chapter, along with the experimental measures.

Chapter 9 presents the results of the second study. The first part of the chapter provides results on the objective measures including navigation errors and tracking task errors. Differences across age and presentation modalities are highlighted. The second part of the chapter focuses on subjective data, including perceived workload, and presentation preferences.

Chapter 10 discusses the results from the second study, including the reasons behind any age and condition differences. Recommendations based on the results and previous research, on how to present route guidance information for older drivers, are discussed.

Chapter 11 provides a thesis summary and produces a full set of recommendations for the design of route guidance systems, taking into account the needs of older drivers. A current commercially available system is evaluated against the current set of recommendations and current areas where improvements are required highlighted.

Chapter 12 is the final chapter highlighting contributions to knowledge made by this thesis, future research and final conclusions.

1.6 Chapter Conclusions

Route guidance systems have thus far taken a technology led approach in their design. This is not acceptable due to the safety critical nature of driving. Older drivers especially are more susceptible to potential distractions such systems could cause, yet they could benefit from these systems even more than other driver populations. This will only be accomplished if the driver needs are addressed and a human factors approach to design taken. Literature revealed very little is known about driver information needs for real-time navigation, especially for older drivers.

This thesis aims to remedy this situation by providing recommendations for the content, timing and presentation of route guidance information, suitable for older drivers.

Chapter 2: Older Drivers & Navigation

2.1 Chapter Summary

This chapter is the first of three covering reviews of the literature on the older driver, navigation and route guidance technology. This chapter discusses the increase in the older driver population, declines in abilities relevant to driving as we age and the consequences of such declines related to safety, behavioural changes and mobility. The chapter also discusses the navigation task and the way in which we build mental representations of our environment and current methods used by older drivers to navigate through unfamiliar environments. Finally the chapter introduces route guidance technology and the benefits it holds for this driver population.

2.2 Introduction

There is much literature on older drivers, covering areas such as *accident involvement* (e.g. European Road Safety Federation 1997; Evans 1994; Schlag 1993; Warnes 1992; Ball & Owsley1991; Automobile Association 1988), *behavioural changes* (e.g. Fildes et al 1997; Burns 1997; European Road Safety Federation 1997; Warnes et al 1993,), and *physiological changes* (e.g. Charman 1997; Barr 1991; Shinar & Scheiber 1991; Kosnik et al 1990; Smith 1986). Each of these areas is important in gaining an understanding of the needs, limitations and abilities, of the older driver, especially in the context of the navigation task.

The navigation task has been studied from a number of angles including how we build mental representations of our environment (e.g. Kuipers 1982; Lynch 1960), and methods used for navigating in unfamiliar areas (Burns 1997; Burnett 1998; Schraagan 1990). It is important to understand these navigation tasks to evaluate the impact route guidance technology will have. Only by looking at all three topics (i.e.

older drivers, navigation, and route guidance technology), can a full understanding of the human factors issues be accomplished.

This chapter aims to review the contribution of previous research to the study of drivers and navigation with particular emphasis on older drivers.

2.3 The Older Driver

2.3.1 Older Driver Definition

The rate of physiological change as we age is not set and so can vary greatly between individuals (European Road Safety Federation 1997). Indeed it is now becoming apparent that there are definite sub-groups within this population e.g. 'young-old', 'old-old' (James & Ehret 1993). Often however for comparative purposes an age defining an older driver has been used. For example Wierwille (1990) used age 50, Walker et al (1991) used 55, Burns (1997) used 60 and James & Ehret (1993) used 65.

Planek (1981) described the age of 55 as being the general point at which the ageing process will degrade driving performance. However if age only begins to show driving degradation at this age then it may be difficult to detect (Burns 1997). For this reason Burns (1997) defined the age of 60 to identify the lower limit of the older driver population, a definition utilised in this research. Throughout this thesis the term older driver is used to move away from the negative overtones of terms such as 'elderly driver'.

2.3.2 Driving Licence Ownership

During the 1960s only 30 per cent of households owned a car. Today the figure has risen to around 70 per cent indicating a substantial rise in car ownership (Automobile Association 1997). As the UK population grows older due to improved standards of living and medicine, and the ability of a person to purchase a car rises due to a growing economy, this figure is set to increase further. Graph 2.1 shows the past, present and future forecasts of the percentage of older persons within the UK's population.

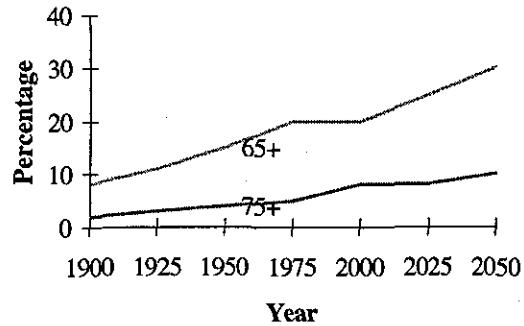


Figure 2.1: Percentage of Population 65 and 75 Years Old and Above (Automobile Association 1997)

Over the next 35 years the proportion of people above the age of 65 will rise from 16 per cent to 23 per cent (Automobile Association 1997), and the proportion of those over the age of 75 will also continue to grow. One of the marked affects of this trend will be the increase in the number of older people in the driving population. Current driving licence ownership in the UK amongst the different age groups is shown in table 2.1.

Table 2.1: Current Driving Licence Ownership within the UK Amongst the Different Age Groups. (Oxley & Mitchell 1995)

	21-49	50-59	65+
Male	90%	88%	62%
Female	80%	55%	17%

More than half of those over 65 currently hold a driving licence. Forecasts of driving licence holding in the UK suggest that over the next 20 years it will be 4 in 5, half of these being women (Automobile Association 1997).

The need for access to a car by older persons is becoming an ever increasing issue. Changes in demographics in conjunction with the poor quality and expense of public transport services, causes concern for older persons as many live in rural areas where this is a problem (Rabbitt 1996). Indeed in many Western European countries those born in the 1930s and later have been the first cohorts to experience majority car ownership from early adulthood, and to bring driving skills and habitual dependence on cars into old age (Warnes 1992). Many older drivers believe that the car is essential or very important for visiting friends, getting to appointments, doing shopping and for holidays. Therefore older drivers feel the need to continue driving in order to retain their independence (Nicolle 1995).

The changes in demographics, increased longevity and increased universality of driving (especially by females) will therefore result in many more older drivers than previously. This has generated concerns that there will soon be an older driver problem (Evans 1994). This description of an increase in older drivers as a problem raises questions as to why there should be concern. There are indeed aspects which need to be addressed, but many of the stereotypes of an older driver do not hold true, as a majority are competent drivers (Warnes et al 1993).

2.3.3 Older Driver Abilities and the Driving Task

" They're slow, they're pompous, and many of them haven't even passed a driving test. The old are a menace on the road."

James Pembroke (The Guardian 1997)

This is just one view expressed of older drivers on the road. The term 'elderly driver', just like 'women driver' is generally understood to be disparaging (Warnes et al 1991). In thoughtless usage the term 'elderly driver' often refers to 'incompetent elderly driver' who causes delays and drives in a slow hazardous way (Warnes et al 1991). These stereotypes are generally false, as many older persons still able to drive are very fit and very capable, and do not draw attention to themselves on the road. Many older drivers on the road today have been driving much of their lives and the increase in older drivers will, in the main be skilled drivers who have been driving for many years, and not novice drivers. Even though they will be greatly skilled in the driving task, there are inevitable declines in abilities as a person ages, which are critical to the driving task.

The driver of a vehicle operates in a multitask environment (see figure 2.2). These tasks can be split into two main categories: *primary tasks* and *secondary tasks.* At the core of this, is the control of the vehicle through a two-dimensional tracking task, which forms the primary task of driving.

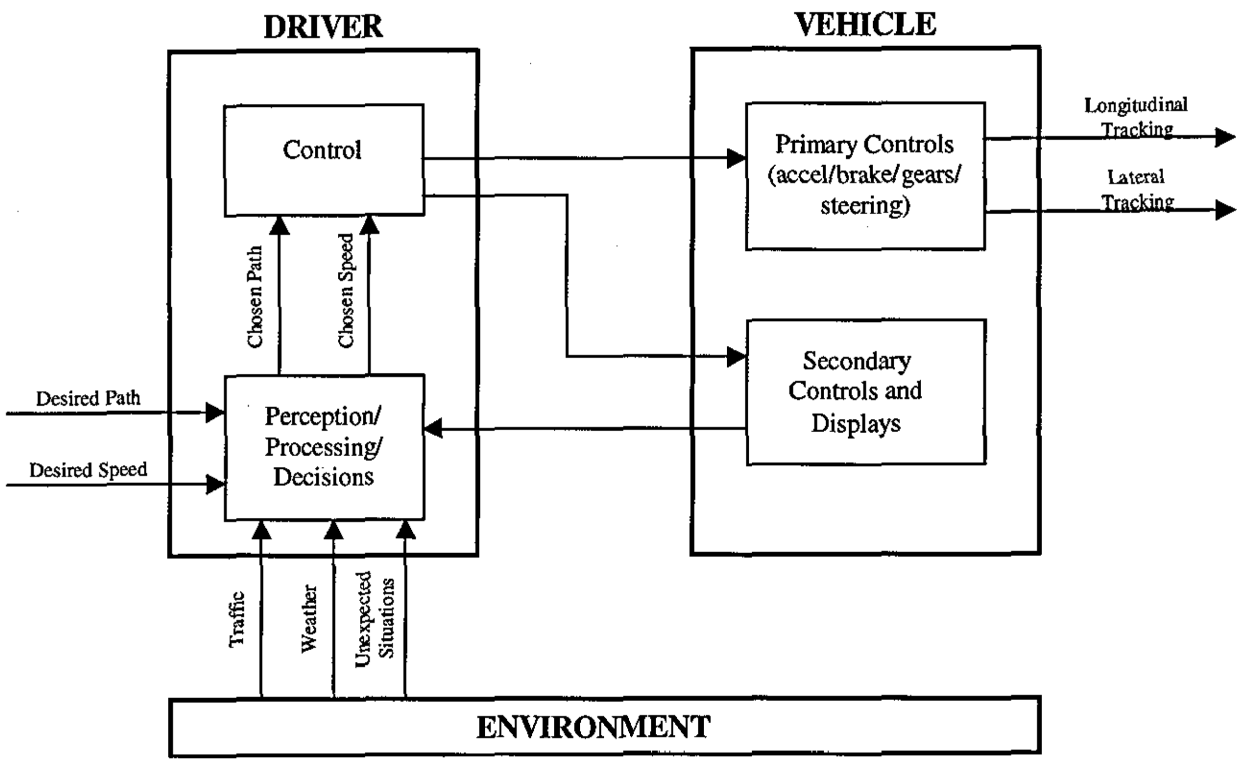


Figure 2.2: Simple mode of the vehicle-driver-environment system (based on Renski 1988)

The longitudinal tracking task is that of speed keeping, with the command input set by either internal goals (travel at a speed so as not to lose control, or not get caught for speeding) or the behaviour of other vehicles, location of hazards, and traffic control signals (Wickens et al 1997). This tracking task is performed through the use of primary car controls i.e. accelerator, brakes clutch gear shift, and the speedometer, and so their reach, visibility and operation require careful consideration. The lateral tracking is commanded by the roadway and requires the driver to maintain lane position through preview (the road ahead) and prediction (the heading of the vehicle) (Wickens et al 1997). This tracking task is performed through the use of the steering wheel, again the reach and operation being critical.

Both of these tasks critically depend on the drivers' ability to clearly see the roadway ahead and maintain visual attention towards it. Any tasks competing for this visual attention must be carefully designed in order to keep the distraction to a minimum, thus having a minimum effect on the tracking tasks.

Secondary tasks that may act as a distraction from the primary task may be external (e.g. observing road signs) or internal (e.g. reading maps, operating radio controls, viewing route guidance systems). These secondary tasks allow the driver to achieve their driving goal (reaching a given destination) in a comfortable and pleasing environment. The design of these controls and displays must minimise the visual attention required by them, thus allowing optimal tracking and maximising safety.

The driving task can be described as consisting of three different conceptual levels, each consisting of different skills and control from the driver. These are best described through a hierarchical structure employed by Janssen (1979).

- Macro Level - Strategic - e.g route planning/ route following
- Meso Level - Tactical - e.g. lane changing, overtaking
- Micro Level - Operational - e.g. turning steering wheel, changing gears.

Activities at the Micro level require very little mental workload. Where as activities on the meso and macro level require decision making and therefore cause much more mental workload (Streeter and Vitello 1986).

As we age there are declines in our sensory, cognitive and motor skills (European Road Safety Federation 1997), all of which are required for the driving task. Age related decline in abilities can be caused either through natural ageing or age related disease. Age related disease effecting driving include dementia (e.g. Kkaszniak, Keyl & Albert 1991), Alzheimer's disease (e.g. Parasuraman & Nestor 1991), and eye disease (e.g. Klein 1991). Of concern with this research are declines through natural ageing, and not age-related disease.

2.3.4 Older Driver Sensory Abilities

Two of the five main sensory abilities are of concern when considering the driving task. These are vision and hearing. Deterioration of these two abilities are among the most common effects of ageing (European Road Safety Federation 1997).

Vision

Driving is primarily a visual task. Some authors estimate that 90 per cent or more of the information essential to the control of the motor vehicle is acquired visually (Olsen 1993). The fundamental driving tasks e.g. route selection, lane position keeping, and the avoidance of conflicts rely entirely or primarily on vision. The problems outlined in this section will predominately discuss the mechanical aspects of seeing, rather than the processes of visual perception.

Visual Acuity

Visual acuity is measured as an index of the ability to resolve fine detail e.g. 20/20 vision. Degraded visual acuity adversely effects the driving of older drivers (Kline et al 1999). This ability to resolve fine details decreases with age and so causes problems such as:-

- *fuzzy images* - such images/objects will not be detected as readily whilst driving as a clear image would be causing problems with road hazard avoidance (Kline et al 1999)
- *reading distance* - the distance at which a road sign could be read would be affected leaving less time for the driver to respond

Accommodation

Accommodation is the ability of the lens of the eye to bring objects into focus. Flexibility of the lens decreases with age and so can cause problems with bringing objects or images into focus, especially nearby objects (a condition known as presbyopia). This can have consequences for the driving task as well as for in-car displays, which use a visual output. For example if a route guidance system gave visual information the time taken to change focus from the road ahead to the screen, would be longer than that of a younger driver. Therefore eyes would be off the road for a longer period of time.

Visual Field

The visual field of a person as they age also decreases. This can be cause for concern due to objects being seen later as they come in from the periphery while viewing the driving environment. Also the displays in cars which rely on the periphery for viewing will need to be at a reduced angle to the line of sight for an older person as compared to a younger person.

Pupil Size/ Condition

The pupil size of an older person is smaller than that of a younger person. This has consequences on the amount of light allowed into the eye and for the purposes of driving can be a problem at night. In addition to this the eye acquires a yellow tint with age which also restricts light intake, along with conditions such as cataracts. Scratching of the lens can also cause problems, especially at night, when light from other car headlights is scattered across the retina (Klein 1991).

Hearing

Hearing is much underused as a sensory channel as compared to vision in the context of the driving task. Deterioration in hearing can occur with age in the amount of sound which can be heard, and the tone levels which can be detected. This not only has consequences for sounds which need to be heard in the environment, but also in the use of technologies which employ an audible output.

2.3.5 Cognitive Abilities

Of interest here are three of the main cognitive abilities required in the driving task, memory, information processing and attention. Declines in these abilities can have an effect on driving, and cause uncertainty for the driver.

Memory

Memory can be very important in the navigational task e.g. remembering routes or roads which need to be taken, or remembering instructions given by a navigator. With age there are declines in both short term and long term memory.

Information Processing

This is the process of taking in information and then making a decision based upon it. More time is usually required by older drivers to process information, and more information may also be required to enable a decision to be made. This can become a problem if decisions are required quickly on limited information within a short space of time. Situations of this kind occur often during the driving task This is particularly problematic for older drivers when negotiating complex junctions.

Attention

Another significant factor associated with the ageing process is the decline of attentional skills. There are three types of attention of concern here:-

- *Sustained Attention* - the ability to be constantly vigilant for a period of time, and able to successfully detect infrequently occurring stimuli.

- *Divided Attention* - the ability to carry out and monitor two tasks simultaneously.

- *Selective Attention* - the ability to appropriately switch attention from one task to another.

Highlighted from research by Brouwer et al (1991) in the DRIVE programme, selective attention is highly correlated with accident involvement, although all are required in the driving task.

2.3.6 Physical Abilities

As one ages motor movement becomes slower and more difficult. In driving this is likely to lead to increased difficulties in using the controls of the car, along with other difficulties such as neck rotation, which is important for checking the road environment, and reversing.

2.3.7 The Perception-Decision-Action Loop

The effects of these declines in ability on the driving task can be seen through the example of the basic process which needs to be constantly adhered to whilst driving. In the driving task the driver needs to constantly perceive information from the environment, make decisions based on this information and then take an action, if any is required. This can be seen as the Perception-Decision -Action Loop shown in figure 2.3 (Malterre and Fontaine 1993).

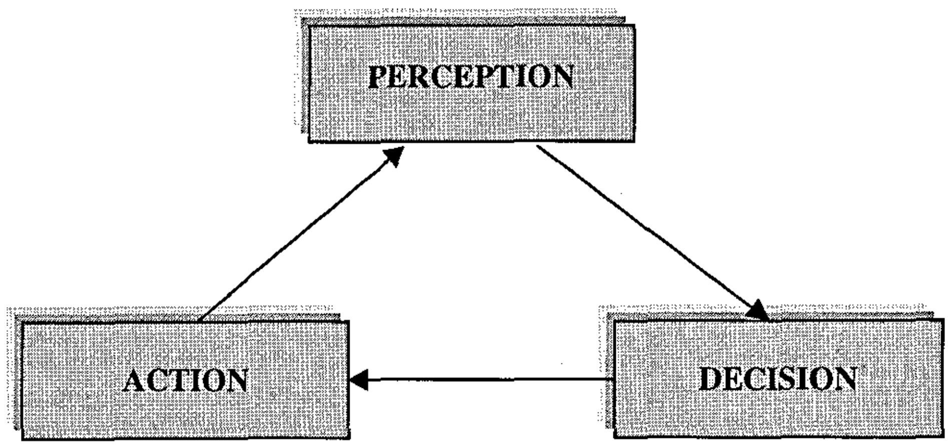


Diagram 2.3: The Perception-Decision-Action Loop

During normal circumstances this process is carried out relatively easily without much effort or concentration. However in certain circumstances such as in approaching a complex junction, problems can arise. On approach to such a situation there are many stimuli in the environment, which will increase the driver visual workload to a large degree, and also affects the mental workload (Verway 2000). If the correct information is not found initially then no decision can be made and no action taken. If this situation continues, then it becomes more critical to take action as the intersection splits into lanes. Here a breakdown is occurring in the loop leading to uncertainty, cognitive overload and stress.

The declining abilities of the older driver mean a higher chance of there being a breakdown in this loop. Locating and processing information in the environment will take longer, leading to a greater period of time being needed in which to make a decision. This is compounded at night if declines in eyesight further hinder the location of information. Due to the increased length of time being taken to locate and process information in order to make a decision based upon it, the driver will become uncertain and so erroneous decisions or dangerous actions may be taken. So here we can see we have an older driver predicament as one of:-

"needing more information on which to base a decision, and more time in which to choose a response"

(Oxley and Mitchell 1995)

Thus more breakdowns in the loop are likely to happen for older drivers especially when a quick response time is require.

2.3.8 Accident Statistics and Situation Occurrence

Accident data show the specific vulnerabilities of older drivers and in which traffic situations and driving tasks they are most at risk (Warnes et al 1993). The number of car accidents in the UK involving older drivers is quite small, but this does not give a true picture of the situation. When the figures are taken in the context of 'per unit mile driven' it can be seen that older drivers are at higher risk than the middle age group of drivers (Guerrier et al 1999). The culpability across the age ranges for accident occurrence is U-shaped. Thus very young and very old drivers are more likely to be at fault in an accident than drivers in the middle age groups.

Further investigation has shown that most accidents occur in certain situations when the declining abilities are exposed to a high level of workload. In a study by Holland and Rabbitt (1994) driving instructors who teach older drivers, suggested that complex junctions, roundabouts and complex situations presented problems for older drivers. More specifically Malfetti and Winter (1987) highlighted commonly observed unsafe driving at junctions by older drivers as:-

- failing to position the car correctly for turning.
- turning from an improper position.
- turning at an improper time or pace at intersections especially when turning left (right for UK).

- failure to signal before changing lanes.
- lack of knowledge of the rules of the road.

The average age of a person involved in a two vehicle accident at an intersection is 52. In the US 40per cent of traffic fatalities and 60 per cent of injuries in the 64+ age group occur at intersections. More than a third of all older driver fatalities occur at junctions where traffic is not controlled at all (Hauer 1988).

It must be noted that junctions are dangerous for everybody, because several risk factors coincide. However in the case of older drivers they can be dangerous without any contributing factors present, indicating a consequence of their declining abilities (Hakamies-Blomqvist 1988).

2.3.9 Older Driver Behavioural Changes

It does appear that older drivers are aware to some extent of their capabilities. A survey by the AA Foundation for Road Safety Research (1993) found that with increasing age drivers tend to adjust their driving behaviour e.g. by avoiding

- heavy traffic
- night driving
- long trips
- busy junctions

Many older drivers believe that such changes in behaviour compensate for declining abilities. Heavy traffic and busy junctions are likely to put high demand on attentional resources, and long trips can lead to fatigue. Night driving will compound any problems experienced with daytime driving, with reduced light reaching the eye and pronounced affects of glare. For normal routine trips these appear sensible behavioural changes and will have a limited affect on mobility e.g. shopping could be done in non peak traffic during the day time.

In conjunction with these factors evidence indicates that older drivers also avoid unfamiliar journeys (Pauzie & Letisserand 1992; AA Foundation for Safety Research

1988; Burns 1997). This begins to put mobility restrictions on the person as they will not venture away from familiar routes.

2.4 The Navigation Task

The primary aim of driving is to travel from A to B. In order to be able to successfully travel to a chosen destination we require navigational abilities. Such abilities include route planning (e.g. using maps, notes, previous knowledge of the area), and wayfinding (e.g. the actual movement and execution of these plans (Burns 1997)). The navigation task then is clearly spatial in its nature, and so requires the ability to solve spatial problems. This ability is based on decision-making, decision execution and information processing (Passini 1984). To gain a better understanding of navigation it is useful to see how we mentally represent, and acquire knowledge of environments in order to promote navigational awareness.

Lynch (1960) looked at how people mentally represent the city they live in, and isolated five distinct elements:-

- *Paths* - paths are a dominant element of a person's environmental image and are classed as channels along which the observer moves. This includes streets, walkways, transit lines, railroads.
- *Edges* - edges are classed as linear elements not considered as paths by the observer. These form boundaries, which close off one region from another and include shores, edges of developments, and walls, all of which are important organising features e.g. holding together generalised areas.
- *Districts* - Districts are medium to large sections of the city, identifiable from the inside and used for exterior reference. Lynch (1960) highlights that most people structure their city to some extent in this way, with differences as to whether paths or districts are dominant depending on the observer and the city.
- *Nodes* - Nodes are junctions, a crossing or convergence of paths, and form strategic spots into which an observer can enter. They can also be seen as concentrations e.g. a street corner hangout or an enclosed square. The concept of a node is linked to the concept of a path as junctions are the convergence of paths (Lynch 1960).

- *Landmarks* - Landmarks form another point of reference external to the observer (i.e. they can be seen at a distance). Moreover they are simply defined as a physical object e.g. building, sign, store, mountain.

As we build up such mental representations then our navigational awareness will be of a high level. The more we travel through areas the more navigational awareness we have for that particular area. How then do we acquire this navigational awareness in order for us to be able to navigate effectively?

At the lowest level our knowledge of the environment begins with landmarks e.g. buildings, statues, which are used for orientation, so this early knowledge is characterised by direct visual images of those features (Wickens 1984). For a landmark to be an effective wayfinding aid when travelling through the environment, it must not only be recognised but linked to knowledge of what action to take in response to seeing the landmark (Blades 1993). Therefore we build up observations consisting of sensory and motor descriptions which can be described as views and actions (Kuipers 1982). The view-action sequence allows us to view a landmark which in turn triggers a response of which way to turn, thus building up route or procedural knowledge (Wickens 1984; Kuipers 1982). This procedural knowledge can take two forms. If we are able to recall those features which trigger the action, then this will allow verbal instructions to be given to someone else. However if only we can recognise them then we have the situation of *"I can take you there but I can't explain how to get there"* (Wickens 1984). This type of route representation is not reversible e.g. getting there one way does not mean you will be able to follow the route in the opposite direction and is also knowledge from a ego-centred frame of reference (Wickens 1984).

Through further navigational experience the person will acquire a configurational knowledge of geographic space which is map-like (Mark 1993), a mental representation of the whole environment referred to as the 'cognitive map' (Tolman 1948). This type of knowledge is known as survey knowledge or metric knowledge (Kuipers 1978;1982). Here the knowledge contains an understanding of how different routes interconnect, and knowledge of different places and areas. A person is able to describe the environment in terms of fixed entities, such as places, paths, and landmarks, linked by metric relations such as relative distance relative angle, and absolute angle and distance with respect to a frame of reference (Schraagan 1990). For example, "using metric knowledge", a driver is able to infer that place A is south of place B; that a turn should be made with a sharp angle; and that a particular route is two kilometres (Schraagan 1990). Satalich (1997) distinguishes between two types of survey or metric knowledge. 'Primary' survey knowledge is acquired while travelling the route itself giving first hand experience. 'Secondary' survey knowledge can be acquired from studying a map which will give partial knowledge.

Kuipers (1978;1982) also separates out what is known as topological knowledge, an intermediate between procedural and survey knowledge. Here the survey knowledge is not complete but of a higher level than procedural knowledge e.g. knowing connections between objects (Mark 1993), and other topological relations such as order and containment (Kuipers 1982).

When we first enter an environment we have not seen before the 'cognitive map' will be empty. It is unlikely many of us will set out to a destination without an aid if we do not know how to get there. So then we adopt aids to enable us to find our way to an unfamiliar e.g. use a map, take route notes, have a navigator in the car. This navigation task in an unfamiliar area is a highly demanding, difficult and stressful task (Ashby & Parkes 1993; Schraagan 1993; Dingus & Hulse 1993) and the methods chosen are not always a success or efficient. This can lead to a considerable amount of excess travel (King 1986). This excess travel, which has been estimated as between 6% and 15% of all highway mileage (Jeffrey 1981) can lead to a monetary loss of 45billion dollars per year (King 1986).

Sixsmith (1990) identified wayfinding as one of the three main problem areas for older drivers. Difficulties in wayfinding can deter older drivers from travelling in unfamiliar areas (Burns 1997; AA 1988) and thus reduces mobility. Pauzie and Letisserand (1992) reported that 49% of people over 65 avoid driving on unknown trips while Rabbitt et al (1996) found that 47% of drivers over 50 years had reduced the amount of driving they do in unfamiliar areas in the last three years.

Contemporary roads and traffic present a greater diversity of conditions for the driver than thirty years ago (Warnes et al 1993) placing a larger cognitive load on the driver. Today's driver has to deal with high speed motorways complex intersections, and congestion. This aids the explanation of complex junction avoidance by older drivers. As the number of decisions that need to be made increases, the level of uncertainty will also increase. If routes with many intersections and many choices at each intersection are avoided this can help reduce attentional demands on the driver. However in navigating in an unfamiliar area this information may not be known or complex route choices and intersections maybe unavoidable.

The problems are often exacerbated by poor environmental design of our road systems. A questionnaire survey conducted by Burns (1997) found that many drivers would miss signs or see them too late, causing navigational errors. Also if road markings are not clear or complex junctions are poorly designed then these features will not only expose older drivers' limitations but also cause problems for all drivers. This can lead to uncertainty and overload on the drivers' attentional resources, as they search for information in a restricted time. In these circumstances incorrect navigational decisions will be made or in the worst case scenario an accident will occur.

2.5 Route Guidance Technology

There have been considerable increases in the complexity and congestion of our road system (Zhao 1997; Hancock et al 1993). This picture of a dangerous, clogged and polluted highway system has stimulated concern (Hancock et al 1993). For the older driver navigating on such road systems compounds already declining abilities, and when carrying out the navigation task itself the extent of these limitations will be exposed. There are now potential solutions to the problems older drivers have with navigation abilities such as route guidance systems.

Route guidance systems have the potential to reduce uncertainty by aiding decision making skills. In such situations as complex junctions route guidance can take some of the decision making away from the driver and reduce the load on attentional resources. For older drivers this may compensate for declining abilities. This presents a solution as they would no longer need to compensate through behavioural changes and their need for mobility is not compromised.

2.5.1 A Brief History of Route Guidance Systems

Vehicle location and navigation aids are not new ideas and have a long history. They have come to our attention more recently as they have only recently started to reach the world market (Zhao 1997). The South Pointing carriage is thought to have been developed around 2600 BC, with reconstructions being made around 1027 AD and 1107 AD. Along with this was the development of the li-recording (distance measuring) drum carriageway (Zhao 1997). The first automotive road map was published in the US in 1895, and mechanical route guidance devices found their way into cars around 1910 one of them being the Jones Live Map (Zhao 1997). Due to errors from the dead-reckoning system used and better marked roads and road maps there was a loss of interest in such systems (Zhao 1997). The interest was resurrected in Japan in the 1970s with the first of a modern generation of route guidance systems, and developed further in Germany and Britain in the 1980s.

2.5.2 Current Technology

The early developments in Japan used visual map displays of the area the driver was travelling, using a marker to indicate the position of the driver/vehicle. Today advances in technology have lead to very sophisticated systems coming onto the market. The uptake of such systems has been strong in America, Japan, and Germany and Britain looks soon to follow suit. Later developments have now led to systems using simple arrow displays and voice communication in order to give 'turn by turn' instructions.

Directions to find your way around the are stored on a simple CD ROM containing maps of every big city in the country. The on-board computer tells you where you are and asks you where you want to go. In turn, the 28 orbiting US military satellites constantly update and pinpoint your position on the computer map (see figure 2.3).

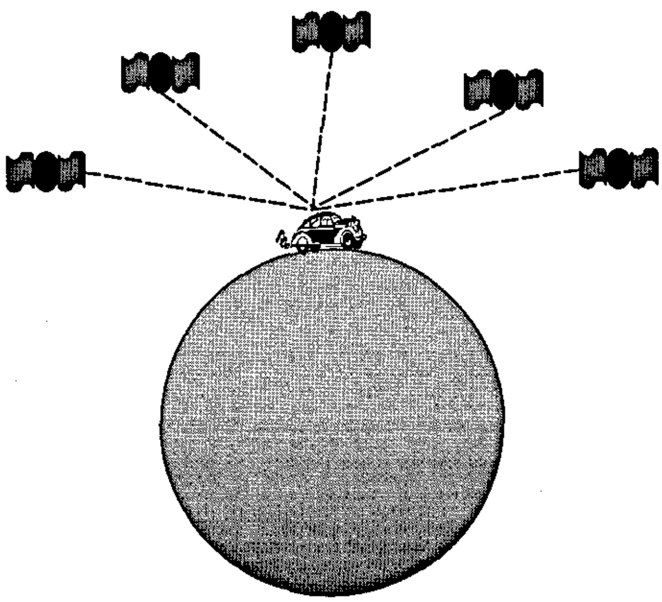


Figure 2.4: GPS - Global Positioning Satellites

After estimating your current position, the system guides you directly to your destination, turn by turn. Figure 2.4 presents a typical route guidance system commercially available in the UK. In conjunction with the visual display verbal instructions are given. The importance of this will be further discussed later on.

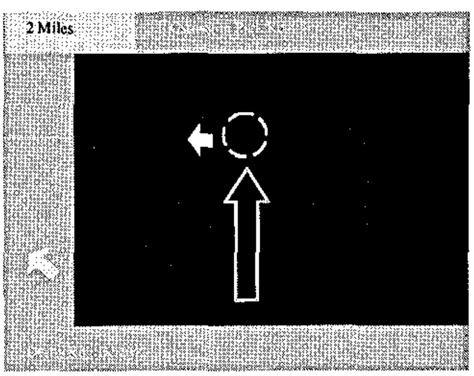


Diagram 2.5: A Route Guidance System

The development and introduction of these systems has thus far been technology led and there are many human factors issues that need to be addressed. It is important that these issues are addressed as the driving task is safety critical so distractions or anything that deteriorates driving ability could potentially cause an accident which could lead to serious injury or death.

2.5.3 Route Guidance System Objectives

So what advantages can these systems bring over conventional methods of navigation? Dingus an Hulse (1993) highlights four objectives which route guidance systems should meet:

Objective I: Navigate more efficiently - allow the driver to locate unknown destinations and travel there error free saving time, money and petrol.

Objective II: Navigate more easily - traditional methods of remembering routes, then travelling and finding signs obscured, or lack of information make navigation a difficult task. Providing all the necessary information will make navigation much easier.

Objective III: Navigate and drive safely - the navigation system should aid the driver, helping reduce decision making and stress. The systems must be designed to minimise distraction to leave maximum driver attention, information processing and response resources for driving in all situations.

Objective IV: Optimise roadway use efficiency - route guidance systems used in conjunction with traffic monitoring technology have the potential to divert drivers when traffic begins to build up avoiding jams and congestion. This in the long run will make the roadways more efficient and save the drivers time and money.

In meeting these objectives there are many human factors issues which need to be considered. The nature of these systems and the environment in which they are used has led them to be described as one of the biggest human factors challenges to date (Dingus & Hulse 1993).

Route guidance systems may change the way we build up a cognitive map of an area. This could lead to an enhancement of the cognitive map or a degradation. At a basic level it could be argued that this will depend on the type of information being provided to the driver. With a map display the driver will obtain information about path connectivity, position relative to other areas which along with the view of the environment being driven through could build up a detailed cognitive map very quickly. However if the system only displays symbols then this may keep the driver simply at the procedural knowledge level i.e. see landmark, make turn at landmark. However even here information may aid the development of a cognitive map as the driver has advance warning of the approach to and direction of turn. If this decreases mental workload spare capacity may be available to take in other information from the environment. If you were required to learn a route e.g. use a map and find your way to a destination, you would probably pick up quite a lot of knowledge from that route. If you were then asked to travel the route again you would probably be able to do it without the map/notes. However if when you first travelled the route you had a friend telling you when to turn left and right and where to go when you travelled the route the first time, and then were required to travel the route on your own this would probably be much more difficult.

2.6 Chapter Conclusions

The increase in the number of older drivers on our roads has led to concern due to declines in abilities as we age. Evidence of the effect this has on driving ability can be seen through the disproportional accident rate older drivers have, compared to other drivers. Older drivers do become aware of declining abilities, demonstrated through changes in behaviour e.g. avoiding night driving due to declines in visual abilities. Older drivers also avoid unfamiliar journeys, as they find the navigation task difficult. Uncertainty at junctions can place a large cognitive load on the driver, as they search for information to make a decision of which way to go. Cognitive overload in such situations can cause navigational errors or accidents.

Route guidance systems have the potential to aid the older driver in the navigation task by reducing levels of uncertainty in the navigation task. In order to meet this objective careful consideration of the human factors issues is required. It is critical to make sure the system is designed to meet the needs of the driver. Failure to do so, could result in the system distracting the driver and thus itself threatening safety.

Chapter 3: Human Factors Issues of Route Guidance Systems

3.1 Chapter Summary

This chapter considers the human factors issues in the design of route guidance systems. The first part of the chapter details these issues. The second part of the chapter discusses driver information needs in reducing uncertainty, situation awareness and expectancy in the navigation task. Finally empirical studies on the navigational information needs of drivers and timing issues are reviewed and discussed.

3.2 Introduction

The development and implementation of route guidance systems has generally been led by the capabilities of the emerging technologies. Route guidance systems possess the potential to aid the driver in the navigation and driving task by reducing mental workload, but also carry the potential to overload the driver. This can result in distraction, confusion and cognitive overload leading to poorer driving performance, which in turn will decrease safety (Burnett and Joyner 1997; Ross 1993; Moss & Triggs 1997). Human Factors professionals have been concerned with the severity of driver distraction which may result (Srinivasan & Jovanis 1993). Accident reports from Japan, where route guidance systems are in much wider circulation, have provided just cause for such concerns. In the first part of the year (January to June) in 1998 there were fifty nine accidents in Japan, resulting from the use of route guidance systems (Japanese MOT 1998). This led to ninety-three injuries and one death. 73% of the accidents occurred while when the driver was looking at the system display. So it is of critical importance when designing new in car systems to ensure the driver will not have to direct their gaze away from the road scene for long periods (Lamble et al 1999). There should be a balance between providing the driver with a useful and timely aid and not distracting them from the primary task of car control.

The primary aim therefore in the development of such systems is to ensure safety, efficiency and usability and minimise the mental workload of the driver (Dingus & Hulse 1993; Brown 1993).

For route guidance systems to be successful and acceptable, driver needs for navigation information require identification. Older drivers will make up a larger proportion of the driver population in future, and would benefit from driver support. Age related declines in spatial ability suggest that older drivers may have diminished navigational skills, therefore increasing the likelihood of getting lost (Federal Highway Administration 1995). Sixsmith (1990), identified navigation in an unfamiliar areas as one of the three main problem areas for older drivers. Hence special attention will be paid to the human factors issues and older drivers.

In order to enhance the safety of these systems using good human factors design there are a number of questions, highlighted in the literature, that need answering for the driver population being targeted (in this case older drivers):

- What information is required to reduce navigational uncertainty (i.e the information content)? (e.g. Alm 1990; Burnett & Joyner 1996; Ashby & Parkes 1993; Schraagan 1991). This question concerns itself with the actual information needs of the driver at a fundamental level e.g. distance information, landmark information etc.
- When should the information be presented? (e.g. Ross et al 1997; Burnett & Joyner1996; Kishi & Suigiuira 1993). This question concerns itself with the actual point in time of when information should be presented to the driver e.g. the time or distance from a junction that a directional command should be given.
- How should the information be presented? (e.g. Burnett & Parkes 1993; Verway 1993; Ross et al 1997). This question concerns itself with modality (e.g. should visual or auditory displays be used?) and display design (e.g. for a visual display should maps or symbols be used? For an auditory system, how long/short should the message be?).

These basic questions are issues that require re-examination in the context of new technological developments (Sivak & Flannagan 1993). This chapter reviews the literature on the first two of the four questions highlighted above namely driver information needs for the navigation task (information content) and the timing of this information. The literature on the third questions is covered later on in the thesis (see chapter 7).

3.3 Driver Information Needs (Information Content)

The first and most fundamental issue in the design of a route guidance system is the content of the information which the system provides i.e. what particular pieces of information will aid the driver in the navigation task (Rothengatter 1995). The question of 'what' to present to the driver needs to be studied in the context of the limitations of driver information processing capabilities. Navigation through an environment can be seen as travelling along the road system and making decisions at a series of junctions about which way to turn. The driver has to decide as each junction is approached what action, if any, is required. This can be seen as a series of sub-goals, which need to be achieved in order to achieve the overall goal of reaching the chosen destination.

At the most basic level of navigational awareness information of what feature to turn at and which way to turn can be seen from Kuipers (1982) view-action pairs (see chapter 2). So here information is required to identify the correct turn for each decision point encountered. Once it is established where the driver needs to turn, and the direction to turn, the appropriate action can be taken. The situation however becomes more complex depending on the amount of choices there are at a junction. For example with a T-junction there are only two options and the junction cannot be missed (i.e. you will arrive at the junction). A simple left or right instruction will provide adequate information. However if a six-exit roundabout is reached the amount of choices of action is far greater (Alm et al 1992). To begin with, some insight into information needs can be identified by highlighting the choices which are available at a junction, and how those choices can be limited in order to aid decision making.

3.3.1 Reducing Uncertainty

As was mentioned in earlier chapters, the focus of this project is on establishing driver information needs for the process of wayfinding en route i.e. actually travelling the route and making decisions rather than on pre-trip planning. This involves travelling along paths which intermittently converge to form nodes. Paths in this case represent the roads and nodes are the place at which these paths form a junction or intersection. The definition applied to an intersection/junction is the location at which, two different traffic streams cross or merge. The terms junction and intersection are used interchangeably but both refer to the same definition.

The ways in which a number of paths meet at a node in the road environment vary. There are broad categorisations for junction types (e.g T-junctions, Slip Roads, Roundabouts, Crossroads), and within each of these categories of junction there exists considerable variation (e.g. a mini roundabout will require different decisions compared to a large six exit roundabout controlled by traffic lights). At these different types of junction the complexity of decision making will vary depending on their situation, the types of road meeting at the intersection and the volume of traffic. There will be a difference also depending on whether the traffic is controlled i.e. by traffic lights, or if the system is free flowing where no traffic lights are involved. As mentioned earlier the more choices at a node the more difficult it will become to take correct turnings especially when the route being followed is unfamiliar. This can be seen for a number of reasons:-

- It becomes more difficult to locate the correct navigational information, for example, on a road sign as there will be more information to choose from

- The correct lane will need to be decided upon and correct exits selected. The driver must then make the manoeuvres while course keeping and object avoiding.

Effectively the information required by the driver should be that which reduces the number of choices to be made. This makes the decision making process easier thus reducing mental workload and stress, while increasing confidence. Therefore this can be seen as information for the 'reduction of uncertainty' (Rumar 1988).

Examples

To explain further how information can reduce uncertainty two examples are given. They demonstrate the different information required depending on the type of junction.

Example 1

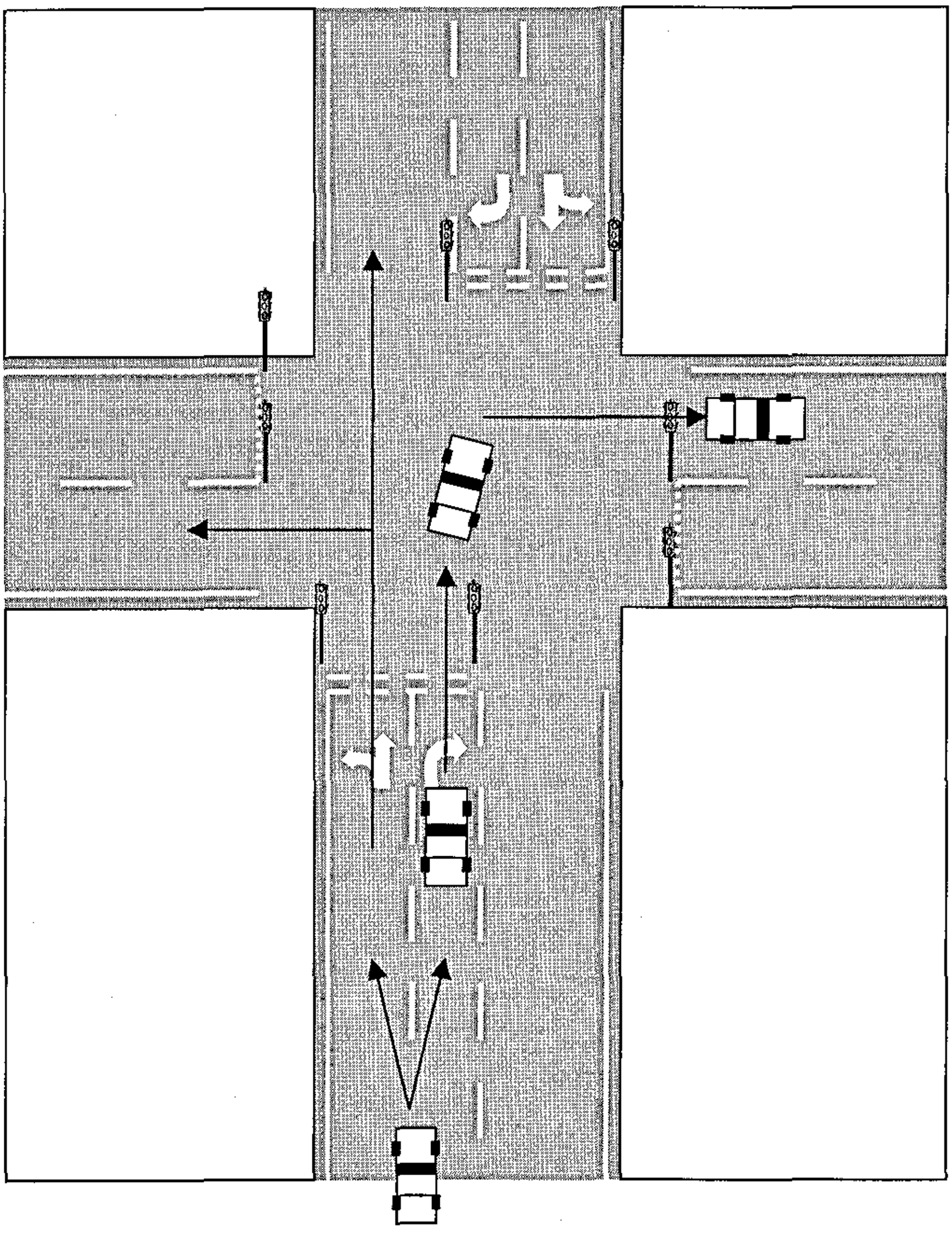


Figure 3.1: Plan view of a crossroads

Looking at figure 3.1, on the approach to the crossroads there are 3 choices (i.e. turn left, turn right, or continue straight on). Without adequate navigational information this can be very demanding in terms of decision making. The driver has a limited period to select the correct lane for the manoeuvre required. With high traffic volumes the task is even more demanding. Provision of a timely left/right/straight on instruction or lane information will immediately reduce uncertainty and decision making required by the driver as the junction is approached, thus reducing uncertainty, mental workload and stress.

Example 2

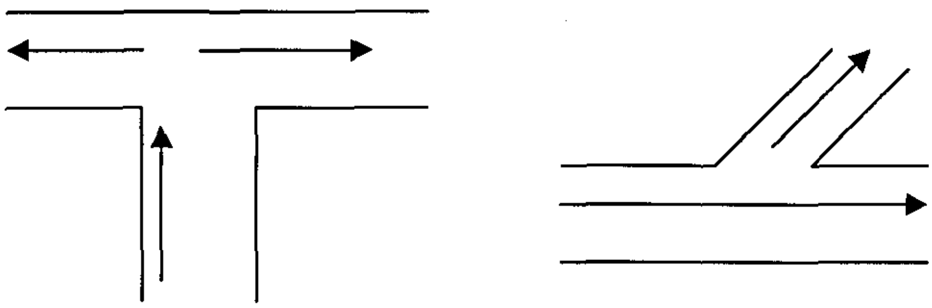


Figure 3.2: T-junction & Slip Road

In figure 3.2 the driver on approach to the T-junction will be asking 'am I going left or right?'. This is a fairly straightforward information need which can be given prior to the junction. In this situation the junction will be reached as the current road comes to an end. In figure 3.2 there is again one decision point but the current road continues past this point. The driver knows the slip road will be on the left, so left/right information is not required. Also the driver is not forced to make a decision at the decision point as they could just drive past it. In this case the information needs may be more to do with warning of a slip road, distance, and junction numbers. This therefore makes a distinction between situations depending on whether you are entering onto a road or exiting it. In the case of a T-junction, if you were approaching from a different side then the information needs change and become similar to that of the slip road.

In both of the examples given only suggestions of the type of navigational information required by driver is given as it must be realised that:

- What is information to one driver may not be information to another (Rumar 1988) and this may vary across age and gender.
- What is information to a driver at a certain point in time may not be information at another point in time (Rumar 1988).

Thus if we are providing the wrong information at the wrong time this will no longer aid in the reduction of uncertainty and reduction in mental workload, but increase both. It is the perceived situation by the road user that will determine the driver behaviour and not the actual physical environment itself. In knowing this and to develop further the possible information needs of driver we require an understanding of situation awareness.

3.3.3 Situation Awareness

Researchers have realised that the first step for successful task performance in decision making and problem solving tasks is the evaluation of the situation (Wickens et al 1997). As has been seen the navigation task requires both decision making and spatial problem solving. Drivers must receive cues from the environment through which they are driving and use them to make sense of the current state of the world (Wickens et al 1997), a process termed situation awareness. Endsley (1997) defines situation awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Endsley (1997) describes situation awareness as having three levels, each of which is described below:

Level 1 - This is the first step to achieving situation awareness and is classed as perceiving the status, attributes, and dynamics of relevant elements in the environment. For example when driving through an environment a driver needs to be able to recognise landmarks junctions etc.

Level 2 - Level 2 situation awareness is comprehending the significance of the elements in level 1 based on one's own goals e.g. when driving being able to determine one's progress along a route based on the environmental cues in level 1.

Level 3 - Level 3 situation awareness is the projecting of future actions of the elements in the environment. This again can be applied to driving in detecting future collisions with other vehicles or in the case of navigation being aware of future decision points in order to have the knowledge and time to choose a favourable course of action.

If this model is applied to the navigation task we can see that the integration of a route guidance system can aid the situation awareness, especially so at level 3 as information on the future environment can be provided to the driver. Also the situation awareness and decision making is influenced by information processing mechanisms, long term memory stores and automaticity, which in turn are affected by abilities, experience and training. Again deficiencies in any of these can be compensated for by the input from the route-guidance system, but it must match the goals and objectives of the driver along with their expectations as these again effect situation awareness and decision making. So here we can see the benefits of providing navigational information to the driver but it must be relevant information or there will be conflicting information from the system and the driver's preconceptions and expectations.

3.3.4 Expectancy

This expectation in the driving task is very important. Standardisation of road layouts and sign placements by traffic engineers will lead drivers to expect certain traffic behaviours and information sources (Theeuwes & Godthelp 1995). Design of highways and traffic control devices should always ensure the unexpected can be forecast by the driver. The qualities of a route guidance system here need to follow similar rules and fit in with driver expectations. As with road signs prior information can be given to the driver, the advantage being for the route guidance system is that no environmental search need take place. For example, if the driver is given prior warning of an approaching roundabout and is told they need to turn right then the driver from experience will already have expectations of what manoeuvres are required at a roundabout. Therefore they will know that if there are lanes present on the run up to the roundabout then the right hand lane will be required for the turn, thus the decisions and preparation can be made prior to arrival. A driver not prepared for the arrival of an intersection may engage in hazardous manoeuvres such as sudden lane changes or running a red light (Endsley 1995). Therefore if the navigation system delivers information which is inappropriate to the particular driver the consequences are severe e.g. the driver may reject the information; the driver may not understand the information; the driver may take a long time to process the information. Thus the usefulness of the system is degraded and the safety of the primary task is compromised (Brown 1993)

It is critical from the literature discussed thus far that the driver's needs are identified in order to give the driver information which matches their perceptions, pre-conceptions, and abilities in the driving and navigating task. Identifying these needs for navigation information is a difficult task but a good start is to look at how we currently find our way in unfamiliar environments

3.4 Driver Navigation Information Need Studies

In order to look at the navigation information needs of drivers current methods of navigation through unfamiliar areas are of interest. Ashby & Parkes (1993) highlight that the effective and acceptable route guidance system will depend on the current methods employed by drivers for the navigation task. A number of studies have been done to look at the information needs of drivers. These include questionnaires, extracting information from the driver's cognitive map, route description and field trials, and evaluating the performance of drivers when presented with certain types of information. This section details these studies.

3.4.1 Questionnaire Studies

Burns (1997) conducted a survey of older drivers looking at wayfinding strategies and information needs focussing on differences between older and younger drivers. The section looking at navigation information needs covered three areas:-

- Navigation information needs on major roads
- Navigation information needs in cities
- Turn Information (from a passenger)

Preferences of types of navigation information on major roads were road numbers, place names and junction numbers. There were no age differences apparent for the type of information perceived to aid navigation on such roads. For city or urban roads the three most useful types of information were street names, lane position, and landmarks. However 15% fewer older drivers wanted landmark information than did younger drivers. The reasons for this are not apparent but Burns (1997) concluded it may be at the expense of path information (such as lane information). For turn information from a passenger, respondents requested they provide left-right directions, landmarks and road numbers. Proportionally, more elderly drivers preferred road numbers and more younger drivers preferred landmarks. Burns (1997) highlights that this finding is consistent with preferences for the information needs in city wayfinding.

Burnett (1998) conducted a questionnaire survey in order to establish driver preferences for different types of navigation information when travelling in unfamiliar areas. 149 male and 51 female drivers took part in the survey. The survey also contained a range of ages of drivers to look at age differences. The questionnaire was split into three parts each aimed at different types of navigational information:-

- Usefulness of different types of navigational information
- Perceived effectiveness of different types of landmark
- Preference for style for eight hand written and sketched directions.

Burnett (1998) found that overall, drivers when driving on faster roads e.g. dual carriageways and motorways considered sign information the most suitable for navigation e.g. place names, road numbers and junction numbers. In slower urban environments drivers prefer more context-based information such as landmarks, road layout and street names. It was found that the older the driver the more useful he/she rated a number of different types of route information, specifically compass directions within non urban driving environments were considered by older drivers to be more useful. Burnett (1998) concluded this was due to more navigational experience which allowed for the realisation of the benefits of using a wider range of information.

The five landmarks considered to be the most effective for navigation were superstores, public houses (pubs), railway stations, street name signs and traffic lights. Here older drivers generally rated many of the specific landmarks as more effective for the purposes of navigation e.g. rivers, dip in road, church, cinema and again this was concluded to be because of more navigational experience.

For drivers' preferences for different styles of directions the top four were:

- Sketches that included landmarks
- Sketches with road/street signs
- Instructions with road/street signs
- Instructions with landmarks

For older drivers there was a trend to prefer sketches with road layout more than younger drivers and instructions with street names less than younger drivers.

3.4.2 Route Sketching and Written Descriptions

Another method of trying to establish driver information needs for the navigation task has been to have drivers draw a map or write instructions of a route or area they know well. Alm (1990) conducted some route sketching and written route instruction studies. The two studies conducted were similar in their nature. For the first study 19 participants aged 26 to 55 were asked to provide written instructions on how to reach the Swedish city of Linkoping. In the second study 38 participants aged 20 to 56 were asked to write verbal descriptions and also sketch maps of how to find three destinations in the same area. The participants all had good knowledge of the area and so would have a well developed cognitive map. The participants were told that the information would be used for someone who did not know the area. The information was categorised using the components of the environment defined by Lynch (1960) (see chapter 2). Alm (1990) found that the participants predominately used landmarks, paths and nodes to describe the routes. Landmarks were broken down further and revealed that the most popular were traffic lights, followed by traffic signs, shops, petrol stations and bridges. Alm (1990) also categorised the way the participants instructed a change of direction based on the classification of Garling and Golledge (1989) e.g. global, local and ego-centred schemes. A majority of the participants used ego-centred directions e.g. "turn left" and some also used local and ego-centric directions e.g. "turn left towards the golf course." From these findings Alm (1990) proposed that directions should be given in an ego-centred form with a landmark added for particularly difficult situations for driver reassurance. Investigating age differences did not form part of the study.

Daimon et al. (1997) also produced some route sketch maps and written verbal route description studies. Participants were asked to describe the route they normally take between home and their university in a form that would be useful to someone who did not know the route, using a sketch map in one condition and a written verbal description in the other. 44 participants were used altogether (40 male, 4 female), all of which were good navigators of the area and therefore had a well developed cognitive map. The information from each of the two conditions was again categorised using the components of Lynch (1960) e.g. landmarks, paths, nodes, districts and edges. A majority of the information noted by participants was landmark, path and node information, consistent with the study by Alm (1990). The map sketch methods extracted more information than the verbal description method but in both cases the extracted information was structured according to the network knowledge representation of the cognitive map. Such a representation is not a true reflection of the area but is more structured to using landmarks paths and nodes. Even individual who could draw an accurate map reverted to the network representation when told it was required for someone unfamiliar with the area. Hence Daimon et al (1997) concluded that route guidance system should be designed in a manner corresponding to the network knowledge representation of the route. Again investigation of age differences did not form part of the study.

Burnett (1998) taking a slightly different approach, looked at the navigation information people would note down from a map or a video of a route they were unfamiliar with. 30 participants took part in the experiment 15 in a map condition and 15 in the video condition. All participants were unfamiliar with the areas shown and were instructed to take notes on information needed to drive the route successfully. Burnett (1998) also used a more detailed categorisation scheme than those of the previous studies described generated from literature and a card sorting exercise from the data collected. In the video condition the most prevalent information extracted was ego-centred directions, landmarks, junction type, road/street names and prior turns. Also considered of use for the navigation task were lane information, road geometry, and place names. Of the landmarks used, these included traffic lights, bridges, hedges, trees, and walls. In the map condition participants did not use so many landmarks, and there was an increased emphasis on road/street names, prior turns (i.e. counting turns) and absolute distances. There was also a much more limited range of information used. The top five were ego-centred directions, road/street names, junction type, prior turns and path class. These accounted for over three-quarters of the information in the map condition. Again investigation of age differences was not part of the study.

3.4.3 Field Studies

Other studies have been carried out while performing the driving task. Schraagan (1990) investigated how drivers navigate under normal circumstances. 24 drivers (half male, half female) were asked to 'think' aloud whilst studying pre-determined routes on a map and whilst driving in an unfamiliar area. The verbalisations were categorised under a scheme partly based on Kuipers' theory (Schraagan 1990) these being: street names, road signs, landmarks, topological knowledge and metric knowledge. Schraagan (1990) found that the more attention applied to street names the poorer the navigation performance, with a more elaborate representation of the route leading to a more robust navigation performance. The gender difference found (women performing worse) was put down to the attention to street names rather than other forms of information. Also poor navigation was put down to memory failures rather than the ability to read the map. Schraagan (1990) also found that driving experience did not appear to effect navigational ability. As with many of the other previous experiments an investigation of age was not part of the study.

Daimon et al (1997) conducted a field trial using a question asking protocol method that could be analysed within the construct of the cognitive map. 5 male participants took part in the experiment and were required to drive to two destinations. An experimenter who sat alongside the driver answered any wayfinding questions they asked. The participants were also required to speak about their feelings and thoughts as they drove. A more detailed categorisation scheme was used than that of Schraagan (1990). Participants primarily requested and relied on information about landmarks, paths and nodes, to navigate to their destination. The most frequently used landmark was traffic signals and the most frequently used path was distance to the next junction. In a further analysis of the content of the questions asked Daimon et al found that participants frequently asked turning questions "left or right?", along with distance from current location to the next turn and reference landmarks to confirm the location of the turning point. Age differences did not form part of this study.

Akamatsu et al (1997) conducted an experiment using a car equipped with a navigation system. 8 male participants (half familiar with the area being travelled, and half unfamiliar) were instructed to drive to a destination via three sub-destinations. Whilst driving participants used the thinking-aloud method, which involves the participants thoughts being spoken aloud. Words relating to landmarks were extracted from the recorded comments. Landmarks for this experiment referred to "information used to identify a location" and included features such as buildings, bridges, tunnels, parks and towers; road geometry; the names of streets, intersections and places; and distances and directions to the destination provided by road signs or maps. Akamutsu et al (1997) found that the most frequently reported landmarks were structures and street names, followed by intersection names, distance information, and place names. As before age differences did not form part of this study.

3.5 Discussion on Information Need Studies

The above studies can be seen to vary in the methods used to study the information needs of drivers, and the way information has been categorised. Table 3.1 summarises the studies discussed.

Table 3.1: Summary of Information Need Studies

Author	*Method*	*Categorisation*
Burns (1997)*	Questionnaire	Not Applicable
Burnett (1998)* (study 1)	Questionnaire	Not Applicable
Alm (1990)	Route Sketching	Lynch (1960)/Garling & Golledge (1989)
Daimon et al (1997) (study 1)	Route Sketching	Lynch (1960)
Burnett (1998) (study 2)	Route Sketching	Own Scheme
Schraagan (1990)	Field Trial (using verbal protocols)	Kuipers (1978)
Daimon et al (1997) (study 2)	Field Trial (using question-asking protocols)	Lynch (1960)
Amakatsu	Field Trial (using verbal protocols)	Own Scheme

**Studies with older drivers*

Studies trying to identify the information needs of drivers in the navigation studies vary in both their methodology and categorisation scheme, as can be seen in the above summary table. Only two studies incorporated older drivers.

3.5.1 Methodology Issues

The literature review identified three types of methodology employed to identify driver navigation information needs: questionnaires, route sketching and field trials.

Questionnaires were used in two of the studies covered. Questionnaires are useful for accessing a large number of people to draw knowledge on information required by drivers in the navigation task. Much research conducted on older drivers has used questionnaires for gathering information (Burns 1997). This approach however has limitations when considering real time navigation. Obtaining the detailed requirements of drivers is difficult if it is not clear in what situations, drivers will require information. Thus it is difficult to design questionnaires to obtain this information. Also the driver is not performing the actual task so the information indicated as ideal, may not be practical or may not be the best information to provide.

Three of the studies employed route sketching to identify the navigation information needs of drivers. There are two alternative ways of doing this, either producing sketches/notes based on the actual observation of a route or producing sketches/notes on a route which is familiar. In the first instance drivers are observing a route to produce sketches/notes so the route can theoretically be travelled at a later date (e.g. Burnett 1998). In the second instance a driver produces sketches/notes on a route they are familiar with, in order to allow someone unfamiliar with the area to travel that route (e.g. Daimon et al 1997). It is the sketches/notes in each case which are analysed. The argument for this method is that route guidance systems should present the types of information represented in their cognitive maps of the environment (Alm 1990). However this may not be as ideal as claimed. The drawing of maps and sketches is essentially route planning, which may be wholly different from information required for real time route guidance. The driver will have no other source of information as they drive and so the sketches/notes will reflect this (e.g. confirmation landmarks so the driver knows they are on the correct road).

Verbal protocols were another method utilised for the identification of driver navigation information needs, during field trials. There were two alternatives here, standard verbal protocols (e.g. Schraagan 1990) or question asking protocols (e.g. Daimon et al 1997). Standard verbal protocols involve the driver verbalising the information they are using as they travel through the environment. This produces real time navigation information being utilised by the driver as the they actually perform the navigation task. However the problem with standard verbal protocols is that they are not a natural process to the driver and are difficult to perform as the navigation task itself is highly demanding. The driver may also report information that has little bearing on the navigation task, and omit major or minor influences (Parkes 1991).

Further to this, drivers need to have looked at a map (or some other form of navigational information) in order to be able to perform the task of navigating in an unfamiliar area. This may bias the information attended to (e.g. street names), rather than be a true reflection of the most useful information required. One way to negate some of these problems is to employ question asking protocols. In this situation the driver asks the experimenter (who knows the route well) for any information they require as they navigate. In this situation drivers have to ask for information they actually require to be able to complete the task. Also the process of asking questions is more natural to the driver than verbalisations. Further to this, question asking protocols allow the timing of information to be acquired by noting the point in time the question was asked with respect to the route being travelled.

3.5.2 Categorisation Schemes

One of the problems in grouping together data from the studies in order to gain better knowledge of driver navigation information needs, is that different types of categorisation schemes have been utilised. Most of the studies have used the research related to cognitive maps in order to categorise the acquired information (e.g. Lynch 1960). These categorisation schemes however are of a very high level simply placing all information into one of five or six categories. In terms of route guidance system design, this information serves little purpose to designers as it is too difficult to apply. Burnett (1998), however due to this produced a detailed categorisation scheme to help produce more practical guidelines.

3.5.3 Age

Only two of the studies looked at age factors when considering driver information needs (i.e. Burns 1997; Burnett 1998). In both cases there were differences identified between age groups. This indeed gives good background to the needs of older drivers in the actual navigation task, but does not provide detailed information directly applicable to the design of route guidance systems.

3.6 Timing of Navigation Information

Timing is critical in meeting the driver's navigation information needs as driving takes place through time and space. There are many issues associated with the correct timing of navigation information. Presenting information too early can put extra demand on the driver's memory. Presenting information too late can put extra temporal demands upon the driver, causing manoeuvres to be missed, or late braking (Nicole 1995; Dingus & Hulse 1993; Ross et al 1997; Fairclough et al 1991; Green & George 1995). Indeed current route guidance systems have been found to raise driver workload through inappropriate message timing (Ashby et al 1991). The time between these two limits (i.e presenting information too early and presenting information too late) is narrow and complicated further due to the difference in drivers' functional abilities. Therefore slower processing times might mean that information should be presented earlier to the older driver (Stelmach and Nahom 1993), though again if the information is presented too early the driver may turn down the wrong street, down a one-way street or against a traffic light (Green and George 1995)

Timing is indeed a very complicated issue in the design of route guidance systems and perhaps explains the lack of empirical studies which have been carried out. Not only are there timing considerations for the types of information being given to the driver (e.g. distance information, direction information), the characteristics of the drivers (e.g. older drivers, younger drivers), and the types of road being travelled (e.g. motorways, urban settings), but also the temporal and spatial aspects. The timing of information related to a temporal aspect can be seen as, for example, giving a direction instruction 10 seconds before a junction. In a spatial context the information could be given a certain distance from a junction. Further to this spatial context information could be given in a manner so as to enable the driver to pinpoint the turn in time and space through the identification of a visible landmark. There have been a number of studies, which have covered the timing of information and are addressed in the next section.

3.7 Timing Studies

The need for good timing of navigation information was highlighted by Burnett & Joyner (1997). An experiment was conducted using route guidance systems in real world situations. 24 participants took part in the experiment, and were required to navigate under three conditions.

- Driving to a destination using route guidance provided by a symbol-based system (System 1)
- Driving to a destination using route guidance provided by a symbol-based system (System 2)
- Driving to destination using verbal instructions provided to the driver e.g. "turn left, turn right" given at the experimenters discretion.

Each method for the navigation task therefore utilised different timing of instructions Table 3.2 shows the distance before the junction instructions were given, the distance prior to the junction that the manoeuvres were made, and the distance before the junction participants indicated.

Table 3.2 Indicating and Lane Changing Behaviour on the Approach to a Complex Junction

	Instructions	*System 1*	*System 2*
Mean distance before junction that information was presented.	600 metres	445 metres	71 metres
Mean distance before junction that participants moved into correct lane	303 metres	210 metres	60 metres
Mean distance before junction that participants indicated	203 metres	149 metres	10 metres

Though not in itself providing ideal timings of information the need for studies of this nature is highlighted. However there are few empirical studies in the literature concerning the timing of information.

Ross et al (1997) identified timing as one of the gaps in existing guidelines for route guidance systems and conducted studies with an aim of producing quantifiable results. Fifteen participants were used (age range 24-62). The instructions used were auditory instructions e.g. "Take the next left turn" considered to be the most appropriate primary source of route guidance information. It was noted that in a working system visual displays should be used for back-up information, and should include direction of next manoeuvre, current position, road layout, distance to next manoeuvre, landmarks, street names/relevant road signs, and distance to destination. The timing of verbal instructions for the manoeuvre of 'leaving the current route' (i.e. side-roads, slip roads) was under investigation as this was seen to be the highest priority regarding the importance of timing. Subjective preferences as well as the recording of vehicle control were the measures used. The vehicle's speed at the given instruction and the distance to the junction when the subjective preference of the instruction timing was give as "okay" were used for the subsequent analysis and the production of equations for appropriate timing. These can be seen below:

*Preferred Minimum Distance = (Speed * 1.637) + 14.799*
*Ideal Distance = (Speed * 1.973) + 21.307*
*Preferred Maximum Distance = (Speed * 2.222) + 37.144*

This study was limited due to the fact that only one junction type was used (Ross et al 1997), though it could be applied to other situations. Most of the instructions were also given on a road where no signs where present. Ross et al. (1997) suggest that the timings where signs are present need to be prior to the sign so the driver has the chance to match the information to the environment. Timing also needs to consider message length (in this study the onset of the instruction was classed as the start of the verbal instruction).

Kishi & Sugiura (1993) looked at the timing of the information required to make lane changes followed by a right turn in a city area. 6 participants took part in the experiment, each performing ten turns. The information identified as necessary for making the turn was lane change direction (left or right) and identification of turning point landmarks. The distance between the point where the subject was instructed to begin the lane change and the point where the subject completed the lane change was the measured distance required for a lane change. This distance was found to be highly correlated to the vehicle speed, the number of lane changes, the number of signals passed, and the number of vehicles that passed. From these results Kishi &

Sugiura (1993) identified critical timing of the navigation information shown in table 3.3.

Table 3.3: Timing of Information Required to Make Lane Changes

Information	*Timing*
Lane change direction right or left	When a driver can select a proper lane before making turn (700m before intersection)
Identification of turning point landmarks (e.g. intersection sign, traffic signal, pedestrian bridge, configuration of intersection)	When landmarks become recognisable.

As with Ross et al (1997) an investigation of age differences did not form part of the study and the timings for only one type of manoeuvre were being determined.

Green and George (1995) conducted a two part experiment to examine how far from an intersection an auditory route-guidance system should present the final turn instruction (e.g., "Turn right"). 48 participants took part in the experiment who were split into three age groups, these being 16 young (ages 18-30), 16 middle aged (ages 40-55), and 16 old (ages 65 and older). In the first part of the experiment drivers followed instructions from a simulated in-vehicle navigation system e.g. ("In approximately 2 miles, turn right at the traffic signal"), responding "Is this it?" when they thought they had reached the desired intersection. The navigation system then responded with "No, continue..." or "Turn...". The drivers response criterion was the latest moment they would feel comfortable hearing the turn message. The distance from the vehicle when voice guidance was requested to the intersection was recorded and formed the dependent measure. In part two of the experiment the participants repeatedly approached two known intersections for which advance turn information was not provided. The driver was again to request turn information at the last moment they felt comfortable. After the second intersection the drivers on now hearing the message at a given timing, categorised the timing as a bit too late, a bit or much too soon, or okay). This process was repeated for all drivers until the message timing was classed as okay. In part one of the experiment, significant effects for the main dependent measure of distance before junction were found for the age and sex of the driver, the approach speed and the direction of the intended turn. The same significant effects were found for part two of the experiment also. There was only a small amount of difference in the desired distance between the two methods. For this reason and also because of greater efficiency Green and George (1995) recommended the second part of the experiment as the most appropriate to determine turn message scheduling. From the results Green and George (1995) developed the following equation for distance before junction that a turn message is given:-

Distance (ft) = -260 + 14 (Speed) + 45 (Sex.code) + 26 (Age.code)

Where

Age.code = 1(young), 2 (middle), 3(older)
Sex.code = 1 male, 2 female
Speed (mi/hour)

Again as in the previous studies the information timing has been based on one piece of information being given to the driver for an upcoming manoeuvre.

Green et al (1995) have however produced some overall guidelines for the timing of other information types as well as turn information, based on a message structure tested by Green et al (1993). This message structure consisted of early information, preparatory information and approaching information. 'Early' information warns the driver of an upcoming manoeuvre, and should always be given. The 'prepare' information informs the driver of lane changes and to begin searching for a street, and should only be given if time permits. The 'approach' information which again should always be given, instructs the driver to perform a manoeuvre. So here we can see a build up of information for the driver over time. Table 3.4 presents the message structure and the recommended timings (these timings were suggested for auditory guidance in particular)

Table 3.4 Message Structure and Recommended Timings

Message	*Content*	*City Timing*	*Highway timing*
Early	"In"{distance} "at" {location} {action}	5 secs after turn	15 secs after turn
Prepare	{distance} {location} {action} or {distance} {landmark} {location} {action}	1500m before turn	3000m before turn
Approaching	"Approaching" {Landmark} {Location} {action}	150m before turn	500m before turn

Green et al (1995) based the 'early' information timings on information gained from experiments using navigation systems. Road tests of a visual version of a navigation system (Green et al 1993) showed that drivers looked at the navigation system within a few seconds of completing a turn. It was believed that drivers at this point in time were seeking feedback that they had made the correct manoeuvre. Thus immediate information about subsequent manoeuvres reassures drivers the previous manoeuvre was correct (Green et al 1995). The information for the other two timing categories were based on literature and recommendations from TravTek. Green et al (1995) gives the following example of the messages given at each of the different times

Early: In 3.5. miles at Green Street, bear left
Prepare: In 1 mile at the traffic light at Green Street, bear left
Approaching: Approaching Green Street, at the traffic light at Green Street, bear left.

This message structure approach gives a much more comprehensive view of timings required for different information types and the build up of information over time.

Daimon et al (1997) in their field trial (earlier described in section 3.4.3) were able to take timings of different information types due to their use of the 'question asking protocol' methods i.e. they could identify where in space and time the driver was when they asked a question. Timings used however were not precise but classified as the following:

- Just after turning
- Middle of two turn points
- Just before turning
- Just before departure

In this manner they were able to determine that just after turning at an intersection the driver sought information to determine where the next turning will be, including distance to next turn and identifying landmarks. When the target intersection appears in sight, they ask questions to confirm the name or location of the intersection. They also found that they direct their attention to the next intersection when waiting at traffic lights or when they have spare time. Further to this if the driver had sufficient distance between the current location and the next intersection, they may inquire about the next intersection or confirm that the intersection where they intend to turn is correct.

3.8 Discussion on Timing Studies

The timing studies reviewed vary in the detail of timing information produced, and the types of information (e.g. direction, distance) for which timing was identified. Table 3.5 summarises these studies.

Table 3.5: Summary of Timing Study Literature

Authors	Nature of Study	Results
Ross et al (1997)	Field trial investigating the timing of an instructions for turning into a side road.	Equation for calculating timing of directional instruction
Kishi & Sugiura (1993)	Field trial investigating the timing of an instruction for making a left or right turn	Specific recommendation for the timing of a turn instruction
Green & George (1995)*	Field trial investigating timing of instruction for making a left or right turn	Equation for calculating timing of directional instruction
Green et al (1995)	Theoretical recommendations	Specific timings of different information required on leaving a junction (e.g. distance), preparing for a junction (e.g. landmark) and approaching a junction (e.g. a direction)
Daimon et al (1997)	Field trial investigating driver information needs and the timing of these.	General timings for different information requirements.

* *Studies with older drivers*

Three of the studies (i.e. Ross et al 1997; Kishi & Sugiura 1993; Green & George 1995) looked at only one type of navigation information namely the timing of directional information. It is possible that when other information is provided to the driver e.g. distance to junction, junction type, sign information that this may change the timing of the requested turn information. Also the timing of this other information in respect of the navigation task, and reducing uncertainty is also crucial.

The study by Daimon et al (1997) produced timings for all of the information required by drivers during a field trial. Even though the study did not give any precise timings it gives an extremely valuable insight into the approximate timings of certain types of information and how different types of information work together. Thus it may be more valuable to identify timings when different types of information are used together. Green et al (1995) produced some specific timings for the integration of different types of information. However these were based on theory rather than an empirical study.

3.8.1 Age Considerations

Only the study by Green & George (1995) considered age when conducting their timing study. Ross et al (1997) also used some older drivers but did not report on any age considerations. Importantly Green & George (1995) did discover age differences in the timing of the information and added a weighting code to the equation to account for this. However this study did only cover turn information, and as mentioned above, the timings may change depending on what information is given prior to directional information. No research has provided conclusive results on the best timings of all types of navigation information, along with the variation depending on the driver group.

3.9 Chapter Conclusions

This chapter identified the human factors issues of route guidance system development. Specifically covered was the content and timing of information that should be presented by a route guidance system. In order to look at information content, literature was reviewed on driver information needs for the navigation task. The literature revealed that relatively few empirical studies had been carried out. Of those studies conducted most produced information at too high a level to be of practical use to designers, and only two questionnaire studies considered the information needs of the older driver. These two studies found some age differences in navigation information requirements.

Considering the timing of navigational information, there was again very few empirical studies. Of those studies conducted most only considered the timing of directional information on the approach to a manoeuvre, one of these incorporating older drivers into the study. Recommendations for the timing of other information requirements (e.g. distance, junction type, sign information), was either theoretical, or not specific in its nature. The one study that did consider age found differences in the timing of direction information.

It was clear from the literature review that there was distinct lack of knowledge concerning navigational information needs, and the timing of these, not only for older drivers but for all drivers. The following chapters aim to remedy this situation by producing a detailed breakdown of the navigation information needs of drivers whilst driving, the timing of these needs, and identifying any differences between older and younger drivers.

Chapter 4: Study 1 Methodology

4.1Chapter Summary

This chapter introduces a field trial conducted to identify the information and timing needs of older drivers and their strategies. Research methodology is reviewed and issues discussed. The second part of this chapter describes the field trial methodology and data analysis procedure. For the methodology details are given about sampling, participants, routes chosen and the procedure. The data analysis is described in detail as this was developed to meet the specific aims of the study.*

4.2 Introduction

The importance of identifying driver navigational information needs and the timing of these was highlighted in the previous chapter. There is limited knowledge in this area, especially with respect to older drivers. An approach was required to enable a detailed analysis of this area, in order to fulfil the content and timing requirements of a route guidance system.

In order to investigate these issues a field trial was conducted. It is argued that the information which a driver actually sees on a journey and identifies as useful for navigational decision making, is the best basis for the content of route guidance information (Burnett 1998). Previous field trial research has employed the use of verbal protocols whilst driving through unfamiliar territory (e.g. Schraagan 1990; Diamon et al 1997). The method used by Daimon et al (1997) was in the form of a 'question asking protocol', as opposed to the 'thinking aloud protocol' used by Schraagan (1990). Kato (1986) reported a number of advantages in the use of 'question asking protocols', the two main findings being:

*Details of this research methodology were presented *at The Second International Conference on Engineering Psychology and Cognitive Ergonomics* (Janes & Galer Flyte 1998)

- 'question asking protocols' are ordinary behaviour, and thus impose less demands on participants in comparison to the 'thinking aloud' method.
- The frequency and sequence of information requirements can be identified.

For the purposes of acquiring navigational information needs of drivers, this method can also be seen to hold a number of further advantages

- In seeking information needs this method not only allows for the collection of data on the type of information used, but also the timing of information requirements.
- Only information required for the purposes of navigation is more likely to be sought (i.e. a lot of redundant information will be removed)
- Using question asking protocols means the driver does not have to see a map prior to driving as they can acquire all information off the experimenter.

This last advantage listed is important. It is conceivable that with a route guidance system present in the car the driver will not look at a map prior to driving to an unfamiliar area. This may change the driver's needs, as they no longer have any concept of the route being travelled (effectively 'blind' navigation). In essence the use of such systems changes the navigational task of the driver, moving away from total use of a cognitive map, to the compliance of the driver to follow explicit instruction. It is therefore important to understand the needs of the driver in the 'blind' navigation situation as compared to a conventional method (e.g. consulting a map prior to driving).

For verbal protocol analysis categorisation schemes based on Kuipers' theory of spatial information, and the elements of a cognitive map proposed by Lynch (1960) (e.g. landmarks, paths, nodes, districts, and edges), have been used to classify data. Even though these methods work well in gaining an understanding of information needs of drivers, it is of too high a level to be of direct use to designers. Burnett (1998) addressed this issue in a study aimed at establishing driver information needs whilst navigating in an unfamiliar area based on their own observation of an actual route, and on information extracted from a map. The analysis was conducted in order to provide information which could be readily understood and applied by the designers of route guidance systems. This led to a more detailed categorisation scheme.

The present study was conducted in order to identify the navigational information and timing needs of older drivers, and their strategies, in relation to the design of route guidance systems. This chapter details the methodology and analysis procedure of the study, which furthers the classification of data appropriate for the better design of route guidance systems.

4.3 Method

4.3.1 Overview

The methodology implemented for this investigation required careful consideration in order to maximise the 'richness' of the data. The procedure involved twelve older drivers (6 male and 6 female), who were used along with twelve younger drivers (6 male and 6 female) for comparative purposes. Participants followed two pre-determined routes of approximately five miles each through a city they were unfamiliar with. Routes were designed to contain a mixture of road types, junction types, and traffic volumes. In one condition the participants were allowed to view a map prior to driving. In the other condition no map was given. Both conditions utilised the 'question asking protocol' method allowing the driver to ask for any information needed in order to reach the given destination. The experimenter who sat alongside the driver provided any information requested. Participants were required to complete a workload assessment after each experimental condition. Video cameras situated within the vehicle (one filming the roadway, one filming the driver) recorded all events and verbalisations during the experimentation.

4.3.2 Experimental Design

The experiment was of mixed design with age and gender as a between participant factors (with age being the main focus of the study) and the condition (map and no-map) as within subjects factors. The experiment was counterbalanced with half of each driver group (older male, older female, younger male, and younger female) being given the map first (on the first route to be travelled) and the other half of each driver group being given the map on the second route to be travelled. To try and control for traffic densities experiments were conducted at non-peak traffic times (between 9.30am-11.30am and 2pm-4pm).

4.3.3 Field Trial Environment

The trials took place in an urban setting including a variety of road environments in a short travel distance. This was economical on the length of time the participant would be driving for, petrol costs, payment of the participants involved and ensured the experiments were completed within certain times of day. It was important to get a mixture of road types and junction types to occur along with other driving situations (e.g. traffic volumes) in order to investigate the navigation task fully. The Derby area was chosen as it has a good mix of road situations and road types, and because the Loughborough based participants should not be familiar with the area. The routes were on the outskirts of the city centre as the desired road situations could be achieved in this area avoiding dense city traffic. Some cities now have restricted access to parts of the city centres and so many people will avoid these areas in particular. The idea was to reflect the type of journey a person may reasonably encounter.

4.3.4 Routes

The two routes used in the chosen environment required careful planning. Firstly the experimental design dictated a within subjects design for the condition (map/ no-map), therefore the routes should be similar. Road types junction types and so on, would need to be similar in both routes creating comparable driving environments for the navigation task. For practical reasons the starting point of the first journey was the finishing point of the second journey. The route characteristics can be seen in the table 4.1.

Table 4.1: A break down of the route characteristics

Route Characteristics	*Route 1*	*Route 2*
Destination	Cinema	New Housing Estate
Mini Roundabout	2	1
Medium Roundabout	1	1
Large Roundabout	2	3
Cross-roads (traffic lights)	2	1
T-junction	1	0
Traffic Light Junction (other than cross roads)	2	2
Turn into side road	1	1
A-road	4	3
B-road	3	4
Pedestrian Crossings	4	4

Each of the routes was approximately 5 miles. The destinations chosen had comparable qualities. The housing and the cinema were both visible from the road before actually arriving, and both had distinguishing characteristics to help identify them on the map and from the road. The mix of junction types was similar with route 1 one having 10 main decision points and route 2 having 9 main decision points both having a mixture of junction types.

4.3.5 Sampling

Participants were recruited from an existing database generated by adverts in a local paper. The field trial required both older and younger drivers for comparative purposes. The profile which the participants had to adhere to is presented in table 4.2.

Table 4.2: Participant requirements

Criteria	*Requirements*
Age	Older drivers - Over 55 years, ideally over 60 Younger drivers - 25 to 35
Health	In good health
Knowledge of Area	No knowledge of South Derby area
Previous Experience of Navigation Experiments	No previous experience of navigation task experimentation.
Years driving licence held	Held licence for at least 5 years
Years of regular driving	Minimum of 5 years driving regular driving experience

The minimum age for older Participants was put at 55 years but ideally 60+ as there is evidence that the declines in abilities discussed in the literature review begin affecting driving at around 55 years old (Planek 1981). To try and make sure this driver group was captured the ideal age was 60+ which is five years on from when age declines begin to become apparent. Ideally it would have been appropriate to observe age groups in older age ranges than this but due to time and money this was not practical. Anyone over the 55 years was assigned to the older drivers group. The younger drivers had to be between 25-35 years ensure any declines in abilities due to the ageing process would not be present. Both groups of drivers were required to be in good health as the focus of the trial was navigation strategies of drivers with any differences between groups being attributable to ageing and not illness. It was also imperative to make sure the participants had not embarked on any navigation experiments before as this may have biased results. Both groups had at least 5 years regular driving experience to ensure any differences between groups were not due to inexperience.

It become clear when approaching persons to take part in the experimentation that some form of bias would occur because a number of people declined to take part because for example they didn't like driving, or were not confident of driving in places they did not know.

This means that drivers that did take part may be more confident drivers or like driving, those who often find themselves navigating in unfamiliar territory or do not find the task daunting. However it could be argued that those who were recruited are likely to be the persons to use the new systems.

4.3.6 Ethical Considerations

Prior to recruitment clearance through the Loughborough University Department of Human Sciences Ethics Committee was granted. This sought mainly due to the nature of the experimentation i.e. in a car, as the task of driving holds many dangers in itself and obviously full concentration is required in order to drive safely.

4.3.7 Participants

The final number of participants was 24. Two data sets were lost due to equipment failure and a third was rejected due to the participant having sound knowledge of the area. Of the 24 participants 12 were older drivers (6 male, 6 female) and 12 were younger drivers (6 male, 6 female). Of the older male participants the average age was 62 years (SD 4 years) and for the older females it was 61 years (SD 2 years). For the younger drivers the six male participants had an average age of 27 years (SD 4 years) and the female participants had an average age of 26 years (SD 2 years).

4.3.8 Apparatus and Materials

Disclaimer form

A disclaimer form outlined the drivers responsibilities throughout the field trial in terms of their responsibility for safe driving.

Instructions

A set of instructions outlining the tasks the participants were to carry out during the field trial, was written so each participant received the same information from the experimenter.

Map

For the map condition participants were provided with an A4 enlargement of the route to be travelled taken from an A-Z of the Derby Area. The route to be travelled was highlighted with a marker pen.

Experimental Car

The HUSAT Research Institute provided an equipped car suitable for the trial. The car was a Vauxhall 2L Cavalier fitted with 2 small video cameras (one pointing at the driver, one at the roadway) and a microphone. Mixing equipment allowed more than one video shot to be recorded at the same time on video equipment also stored in the boot of the car.

NASA R-TLX

For workload measurement a version of the NASA R-TLX (Byers, Bittner, & Hill, 1989) modified for driving (Fairclough, 1991) was used (see appendix 1).

4.3.9 Procedure

Before beginning any driving the participant was asked to produce a valid driving licence and to use any glasses etc. they required for driving. The participant then read and signed the disclaimer. The participant was familiarised with the vehicle controls etc. and the presence of the video cameras explained.

The first part of the trial was a practice run in which they drove to the starting point in Derby under the experimenter's guidance. During this period no observations took place and the video cameras were off. Once at the starting point of route 1 instructions were then read to the driver explaining the tasks involved. At all times it was stressed that driving safely was the primary task and the participant was free to stop at any point. The participant was then allowed to ask any questions on the tasks involved to make sure it was clear they knew what was expected of them.

If the first condition was with the use of a map, this was handed to them with details of the destination and with the instruction that they had three minutes to study the map. In the no-map condition the driver was given the destination and instructed to drive when ready. The participant then proceeded to drive the route. As they drove they were able to ask the experimenter for any information required in order to reach the destination. The experimenter who sat along side the driver had extensive knowledge of the route and so could provide the information requested. A limited assistance policy was used by the experimenter, who only answered the questions asked, and refrained from offering unsolicited assistance. The participant was free to ask for as much information as they wanted. This process continued until the driver had reached the destination. On arrival the driver was directed to a designated parking area. Mental workload measures were then obtained from the participant, using a NASA R-TLX workload test.

This completed the first route. For the second route the same procedure was followed the only difference being the experimental condition (e.g. if they had a map on the first route they did not have a map on the second route). Once the second destination had been reached, the driver again completed a NASA R-TLX test for the route they had just travelled. A questionnaire was then administered to obtain subjective preferences and background information. This concluded the experimental part of the trial. The participant was thanked for their co-operation and any further questions answered.

4.4. Data Analysis

4.4.1 Data Transcription

The audio and visual tracks of the video recordings were transcribed. Every event that occurred was noted along with the time it happened (the start of the journey being 0). Table 4.3 gives a description and explanation of the events, which were transcribed.

Table 4.3: List of events recorded in the driving task

Event	*Explanation*
Question	Verbatim transcription of the question asked by the participant and the time along the route at which it was asked.
Commentary	Verbatim transcription of other information not in the form of a question but relevant to navigation was also noted.
Indicates	The time along the route at which direction indicators were applied (e.g. on the approach to a junction)
Junction Reached/Junction Exited	The time along the route at which the driver reached/exited a junction (the junction was given a number depending on position along the route)
Road splits into lanes	The time along the route at which the road split into lanes - e.g. on an approach to a junction
Moves/Changes lane	Time along the route at which the driver changed lanes.
Slow Moving/began driving normal speed	If the car was slowed by traffic the time along the route was taken when this happened and when the car resumed normal speed.
Stopped in traffic/Began driving	When the car was stopped in traffic the time was noted. Once the car began moving the time was noted again.
Destination Reached	The time upon arrival noted.

The transcriptions were entered into Microsoft EXCEL, giving a spreadsheet of all the events recorded for each subject in each condition. Table 4.4 gives an example of one of the transcription spreadsheets. The left hand column lists the event, the middle column gives the time elapsed since the journey began, and the third column gives any dialogue in the form of a question or commentary. The third column also lists additional notes, where there may be doubt of the context of the question. The table in this form gives a qualitative view of the data.

Table 4.4: Excerpt from video transcription (time elapsed in minutes and seconds)

Event	Time	Dialogue/Comments
Question	*7.49*	What town are we in now?
Question	*8.02*	At this roundabout here I go straight on?
Question	*8.05*	Towards the city centre?
Commentary	*8.08*	Sorry, it's the A5111 (on being corrected of error)
Indicates	*8.10*	
Commentary	*8.13*	These junctions came up a lot quicker than they looked on the map.
Road splits into lanes	*8.14*	
Moves into lane	*8.15*	(moves into left lane as soon as parked cars allow)
Junction 6 reached	*8.19*	(stopped for oncoming traffic)
Junction 6 exited	*8.31*	
Question	*8.37*	Is there another junction coming up?
Question	*8.42*	What type of junction is it?
Road splits into lanes	*8.50*	
Moves into lane	*8.51*	(moves into left lane)
Question	*8.54*	Is there going to be a sign to the leisure park?
Junction 7 reached	*8.55*	(didn't need to stop - lights on green)
Junction 7 exited	*8.56*	
Question	*9.03*	Is it visible from the road?

4.4.2 Data Categorisation

In order to analyse the data it was necessary to make use of a scheme for categorising the questions in the context they were asked. Even though the usefulness of the categories provided by Kuipers (1978) and Lynch (1960) is recognised (see chapter 2), these were of too high a level to provide the kind of data required. As can be seen from inspection of table 4.4, the process of navigation is complex. For example, on approach to junction 6, questions are about the current town the person is travelling in, to directional and sign information. Junction type information is then sought for the next junction being approached (junction 7). In addition the questions switch intermittently from referencing the junction to gaining further navigational information on the destination and its location.

The detailed categorisation scheme developed by Burnett (1998) was chosen as the starting base for the breakdown of the data. Although this was not followed exactly (due to the different experimental methodology employed in this study) it formed the basis of the categorisation of the questions asked. However, the classification of data needed to be extended to take account of timings (e.g. time before junction reached) the context of the questions (e.g. asking for information, confirming information), and the reference target of the question (e.g. the destination, a junction). The breakdown of the data was grouped under three headings

- General Information - Any relevant information not part of question content or timing e.g. number of questions asked, question context, errors, route times
- Question Content - The actual content of the question e.g. whether the question was seeking direction information, distance information
- Question Timing - The timing of the questions in relation to junctions and the destination.

A breakdown of the complete classification categories under each heading is given below, with explanation to their purpose.

General Information

Number of questions asked

The number of questions asked was recorded to indicate how much information drivers required.

Route Times

The primary aim of driving is to reach a chosen destination. The driver may want to do this within a defined period of time (often the shortest time possible). Rout times are an effective measure of the performance of drivers in navigation as uncertainty often leads to slowing down as decisions are made, and errors add extra time to the journey. This has been used effectively in previous research (e.g. Streeter et al 1985). The route times for each of the participants was recorded for each route travelled.

Question Type (QT)

The paper by Kato (1986) on the 'Question asking protocols' methodology identified two types of question that could be asked. The question could be what was termed 'exploratory' or 'confirmatory' depending on the 'intent' of the query. That is whether the question is based on the driver's own hypothesis or beliefs or whether they are seeking information from the experimenter. For example the driver may, on approaching a junction, ask 'which way do I go at the junction?'. In this situation the driver is seeking information and has no intention of doing anything or no hypothesis of what to do. If the driver however, on the approach to a junction, was to ask 'Keep going straight on?', they are then referring to a hypothesis or belief about what the next manoeuvre is and are seeking the experimenter's endorsement of this hypothesis. For the purposes of this field trial a third category was required indicating whether the driver was seeking to confirm their own hypothesis or whether they were seeking to endorse the hypothesis and belief based on earlier information from the experimenter. The three possible question types are given below.

- 'Which way do I go?' - Information - Seeking information to begin with.
- 'Keep going straight on?' - Confirmatory assumption - Seeking endorsement of their own belief when no previous information has been given by the experimenter.
- 'Keep going straight on?' - Confirmatory - When the driver has earlier asked for this information and was now seeking to confirm what the experimenter had previously told them.

The coding of the question could only be identified when taken in the context of the events leading up to the junction. This was easily done as all events were chronologically logged in the transcription.

Error (ER)

Any errors either in the questions (e.g. confirming a left turn when they have already been told it's a right turn) or the driving (taking a wrong turn) were highlighted in order to compare the efficiency of different strategies.

Question Content

Category (CT)

This categorised the information into one of 6 high level categories. The six categories were based on that developed by Burnett (1998). The six categories were

- Direction questions e.g. Which way do I go?
- Distance questions e.g. How far is the next junction?
- Node questions e.g. What is the next junction?
- Landmark questions e.g. Is there anything to help me recognise where to turn?
- Path questions e.g. Is it a main road I turn onto?
- Sign questions e.g. Do I follow the A5111?

These categories are similar to the categories of Lynch (1960), Kuipers (1978) and Schraagan (1990). The information was categorised firstly to get an overall high level picture of types of information asked for and secondly to compare findings with previous research.

Category Element (CE)

The detailed category elements proposed and used by Burnett (1998) were employed to break each of the high level categories into more detailed elements for a better understanding of the exact nature of the questions asked. Table 4.5 gives the detailed elements and examples of the types of questions represented.

Table 4.5: Categorisation scheme for questions asked by drivers (adapted from Burnett 1998)

Category	*Elements*	*Description*	*Examples*
Direction	**Ego**	Direction is defined in relation to the position of the car driver	Do I go left of right?
	Local	Direction is defined in relation to an external reference point	At the roundabout do I take the 2nd or 3rd exit?
	Global	Direction is defined in relation to a system that can be applied universally	Do I head northwards?
Distance	**Absolute**	*Distance define as a precise value.*	How many miles am I travelling on this road for?
	Cost-based	Distance is defined in cost terms (e.g. time)	Am I staying on *this road for* a while?
	Relative	Distance is defined relative to some other marker.	Do I stay on this road until the next junction?
Environment – Node (junction)	**Type**	Information which indicates the form of the *oncoming* junction.	Is that a roundabout approaching?
	Reference	A preposition that references a junction to a manoeuvre.	Do I turn left <u>at the roundabout</u>?
	Angle	Information which indicates the angle of junction	Is it a sharp left turn?
Environment – Landmarks	**Name**	Name of particular class or type of landmark.	Are there any obvious signs of my next left turn like traffic lights or a pub?
	Descriptor	*Additional descriptive information that would* help in identifying a particular landmark.	Is the it a modern building?
	Locator	Information that would help in locating a particular landmark.	Is *it likely* to be on my left?
	Reference	A preposition that references a landmark to a manoeuvre	Do I turn left <u>at the traffic lights?</u>
Environment – Path (road)	**Class**	Information on the class or type of road.	Is it a main road I come across next?
	Lane	Information regarding which lane to take.	Do I need the left lane?
	Prior turns	Information regarding turns along the path prior to an oncoming manoeuvre.	Is it the 2nd or 3rd left I need to take?
	Geometry	Information about the geometrical layout of the road.	Are there any sharp turns or U-bends coming up?
Environment – Signs	**Place name**	Information regarding a place name (on or likely to be on a road sign)	Am I heading towards Derby?
	Point of interest	Information regarding a point of interest name (on or likely to be on a road sign)	Is the destination on a leisure park or industrial estate?
	Road name	Information regarding a road/street name (on or likely to be on a road sign)	Was the next road called Chellaston road?
	Road number	Information regarding a road number (on or likely to be on a road sign)	And it's the A5111 I want next?

Reference Category (RC)

The categorisation scheme proposed by Burnett (1998), did not fulfil all of the aims and criteria required, for the breakdown and analysis of the data in this study. As was shown in table 4.4 the reference of the question changes e.g. the driver could be asking the distance to the next junction or the distance to the destination. A categorisation scheme was developed to take into account the reference of the question. This can be seen in table 4.6.

Table 4.6: Categories for question references

Reference	*Description*	*Example*
Node (junction)	Questions is in reference to a junction.	Is the next junction a roundabout? How far away is the next junction?
Path (road)	Question is in reference to a path	Do I stay on this road for a while?
Manoeuvre	Question is in reference to a manoeuvre (i.e. a deviation from their current path)	How far before I need to turn off this road? What do I next need to turn at?
Driver position	Question in reference to the driver position	Am I in Chellaston at the moment?
Destination	Question is in reference to the destination	How far is the destination from here? Is the destination in Derby?

A note should be made here about the distinction between a reference to a node and a manoeuvre. If the driver specifically asked information regarding the next time they needed to turn from their current path (which was not therefore necessarily the next junction) then this was classed as a reference to a manoeuvre.

Reference Order (RO)

The reference order identifies which junction or which path the driver is talking about e.g. 'What is this road called?, referring to the current path they are on, 'What is the next road called?' referring to the name of a road but the next one on which they are to travel.

Question Reference Made (RM)

This was to note any references made within the question e.g. 'Do I go left?' on an approach to a junction makes no reference to the junction, as compared to 'Do I go left *at the traffic lights*?'. If a reference is made it was then categorized using the scheme devised by Burnett (1998) e.g. *Question Reference Category (QRC), Question Reference Element (QRE).* The name of the reference is also noted under *Question Reference Name (QRN),* which in the case above would be 'traffic lights'. Classifying this information enables common groups of question references to be identified is useful for determining types of landmarks drivers use.

Timing

Route Time(RTA, RTB)

Each time an event occurred or a question was asked, the original transcription provided time elapsed since the beginning of the journey. Once all these times had been put in it gave a final time entry for when the destination was reached, in essence the time it took to travel the route. Knowing the total journey time enabled the time before the destination was reached to be calculated. Therefore each event or question asked generated two route times

- The time elapsed since journey began.
- The time until destination reached.

Figure 4.1 illustrates how each question generates the two times described.

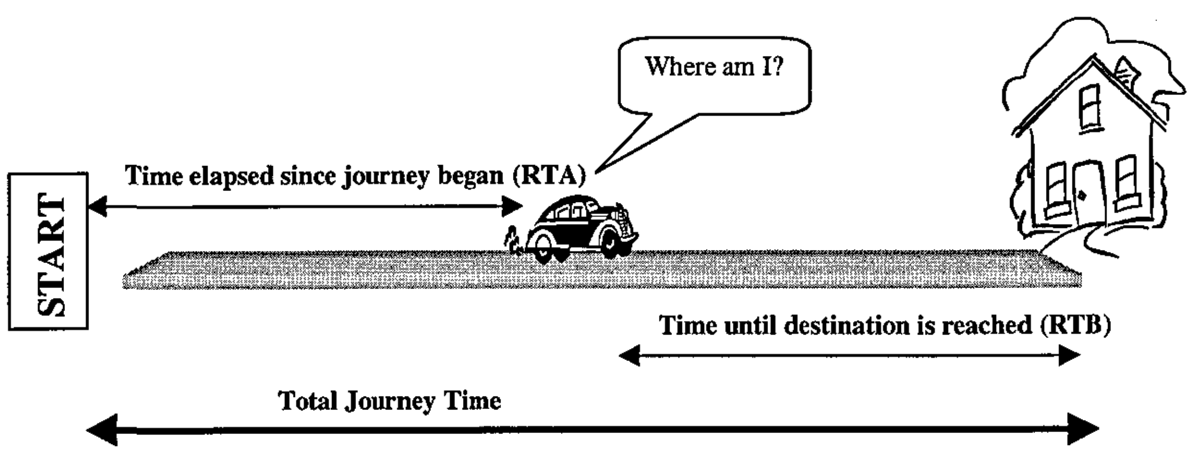


Figure 4.1: Illustration of the two times calculated at the occurrence of a question being asked.

This was done to help identify patterns of information request over time as part of the main goal (reaching the destination) to be assessed in the following manner.

The time elapsed since the beginning of the journey has a count from 0 i.e. start route at 0 seconds and time elapses during travel. This enables patterns of information request (if any) at the beginning of the routed to be identified (as everyone has the same starting time of zero seconds). The time elapsed since the journey began however would not identify any similarities in information patterns towards the end of the route should they occur, as it will take people different times to finish the route depending on traffic, speed of travel. Calculating the time of an event before the destination is reached also gives all data a countdown to zero e.g. 50 seconds before the destination is reached, 40 seconds before the destination is reached. This then enables information patterns in the later part of the route to be identified (as everyone has the same finishing time of 0 seconds). These two times are categorised as follows:

- Route Time After (RTA) - Time elapsed since the beginning of the journey.
- Route Time Before (RTB) - Time before the destination is reached.

The two times taken also enable analysis of whether the majority of questions fall in the first part or the second part of the journey. This is achieved by comparing the two times (RTA RTB) for each question. If the RTA is greater than the RTB, then the question will fall in the second part of the journey and visa versa. Figure 4.2 illustrates this point.

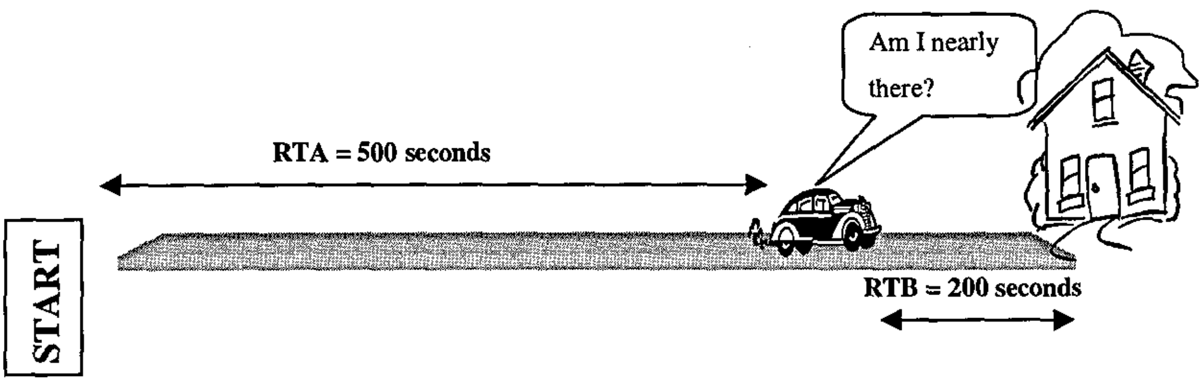


Figure 4.2: Question falls in latter part of the journey as RTA is greater than RTB

Time Before/After Junction (TB/TA)

Reaching and leaving a junction was classed as an event. This information enabled times to be calculated for all questions asked relevant to the junctions i.e. the sub-goals of navigation task to meet the needs of the overall goal (reaching the destination), as the elapsed time since the start of the journey was known (see figure 4.3).

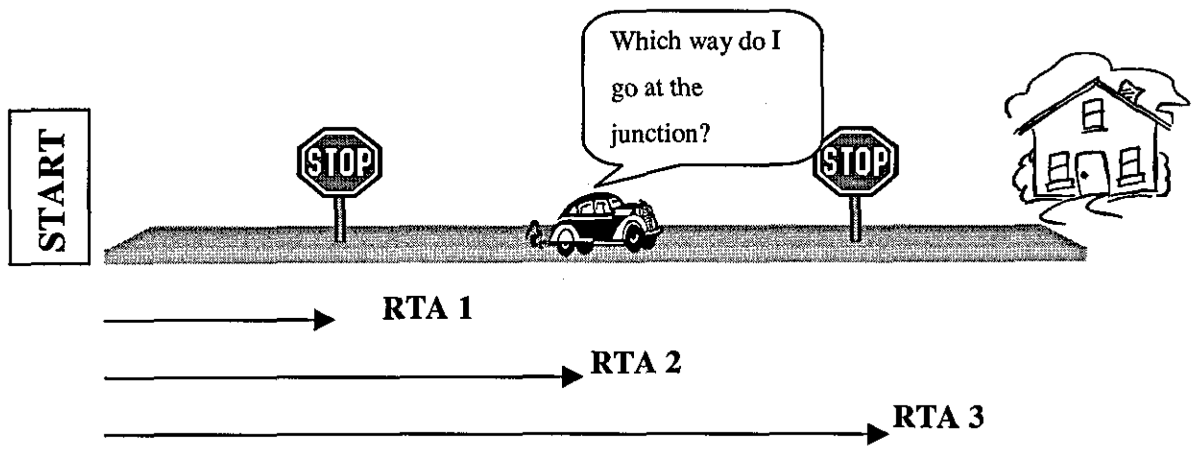


Figure 4.3: Illustration of calculation of times relative to junctions

Every time a question was asked it was possible to calculate the time elapsed since the last junction (RTA2 minus RTA1) and the time before reaching the next junction (RTA3 minus RTA2). Thus each question generated two times. As with the overall route times the same principles were followed. By taking times to locate where in between the junction the driver is it gives two counts i.e. starting from zero (time elapsed since leaving the last junction) and a countdown to zero (the time before reaching the next junction). Figure 4.4 illustrates this point.

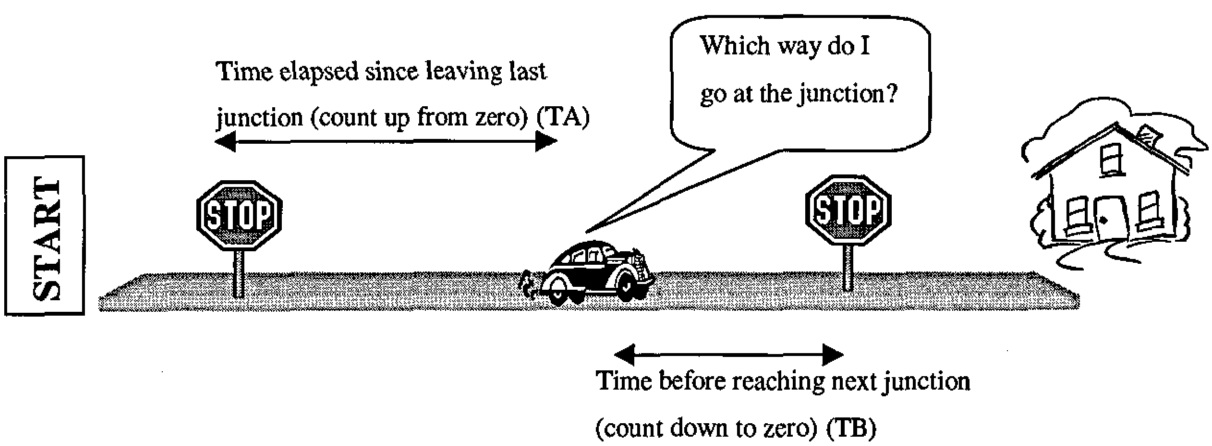


Figure 4.4: Illustration of the two times taken relative to junctions when a question was asked

Taking the time before a junction would show any patterns of information occurring on a junction approach, and the time after a junction would show any information patterns occurring on leaving a junction. These two times were categorised as follows:

- Time After Junction (TA) - the calculated time elapsed since leaving the last junction.
- Time Before Junction (TB) - the calculated time before reaching the next junction

Again the two times together make up the time between the two junctions. The two times taken enabled analysis of whether the questions were asked on the junction approach or junction departure, following the same principles explained for the route times. For example if TA was greater than TB then the question would be classed as asked on junction approach. If TB was greater than TA then the question would be classed as being asked on junction departure (see figure 4.5)

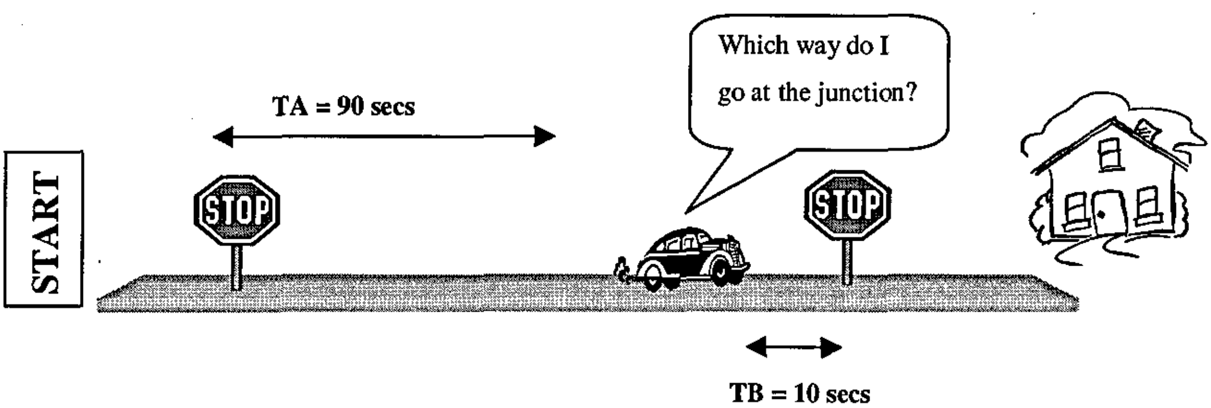


Figure 4.5: TA is greater than TB - question classed as being asked on junction approach.

4.4.3 Example of Data Analysis

To help illustrate the analysis method described, table 4.7 gives an example of the breakdown for the question 'Which way do I go at the traffic lights?'.

Table 4.7: Categorisation for the question 'which way do I go at the traffic lights?'

RTA	*456secs*	Time elapsed since journey began to when question was asked.
RTB	*302secs*	Time elapsed from when question was asked to end of journey.
ST	*Moving*	The status of the vehicle is that it is moving and not stopped in traffic or at a junction when the question was asked.
JN	*5*	This is the fifth junction reached since the journey began.
QT	*Info*	The question is asking for information on a direction as opposed to trying to confirm a direction.
CT	*Direction*	The question is classified as directional (after Burnett 1998).
CE	*Ego*	The question classified further as an ego-centred directional question (after Burnett 1998).
RC	*Node*	The direction is being asked in reference to a junction.
RO	*Next Junction*	The junction being referenced is the next junction being approached.
RE	*Xroads*	The type of junction being approached is a crossroads.
TA	*50secs*	The time elapsed since leaving the last junction to the question being asked.
TB	*10secs*	The time between the question being asked and the junction being reached.
RM	*Yes*	Indicates there was a reference made within the question to the junction being approached.
QRC	*Landmark*	The question reference is classified as a landmark (after Burnett 1998).
QRE	*Landmark Name*	The question is classified further as a landmark name (after Burnett 1998).
QRN	*Traffic Lights*	The landmark referred to in the question is named.
ER	*No*	No error in the question asked.

Data Treatment

Each of the questions was put into excel and coded using the above categorisation scheme. This gave a pool of 742 questions. For the analysis of the data each code was given a number. Due to the fact that some drivers asked more questions than others data was transformed into percentage of the different types of questions asked by each participant at each point in time. The data was then transferred to SPSS for descriptive and inferential statistical assessment.

Statistical analysis was conducted using parametric tests due to their increased power over non-parametric tests (see Howell 1997 for further discussion on this subject). The nature of the data mainly led to the use of ANOVAs and t-tests (along with some correlation where appropriate), with transformations being performed on the data where assumptions of these tests were not initially met (see Howell 1997). Significance was taken at the 5% level or lower. Further to this the 10% level was seen as a marginal significance (or a trend), due to the amount of uncontrollable variables present when conducting a field trial.

4.5 Chapter Conclusions

This chapter described the methodology and data analysis procedure for a field trial study aimed at identifying the navigational information and timing needs of older drivers and their strategies. Participants were required to drive two routes. On one route they viewed a map prior to driving. On the other route no map was given and so the driver was essentially navigating 'blind'. The methodology was based on 'question asking protocols'. The data analysis procedure was developed to enable investigation at much more detailed level than the breakdown of data employing components from Lynch (1960) or Kuipers (1978) models. The categorisation scheme developed by Burnett (1998) helped provide a basis for the detailed data analysis. Results of the field trial are presented in chapter 5.

Chapter 5: Study 1 Results

5.1Chapter Summary

This chapter presents the results of the field trial. The first part of the chapter reports on the analysis of driver performance and behaviour including number of questions asked, route times, high level categorisation of the information sought by drivers, and subjective measures looking at differences across condition age and gender. The second part of the chapter concentrates on the detailed analysis of the content and timing of questions asked by the drivers, highlighting differences across age and gender.

5.2 Driver Performance and Behaviour

The first section deals with the main driver performance and behaviour in the navigation tasks, looking at the number of questions asked, the type of questions, errors, route times, the high level categories of the information content (e.g. direction, distance), and subjective measures. The analysis will focus on age and condition differences. Any relevant gender differences will also be included due to evidence of differing needs between male and female drivers (e.g. Schraagan 1990; Ward et al 1986)

5.2.1 Number of Questions Asked

The field trial yielded a pool of 742 questions from the 24 drivers who participated. The mean number of questions asked across age and condition can be seen in table 5.1.

Table 5.1: Mean Number of Questions Asked (standard deviation)

	Map	*No-Map*
Older (N=12)	12 (5.2)	17 (8.6)
Younger (N=12)	13 (7.0)	19 (11.1)

A repeated measures ANOVA was used to identify differences in the amount of information used by drivers across condition, age and gender. There was a main effect for condition [$F(1,20)=22.174$, $p<.001$]. Significantly more information was sought by drivers in the *no-map* condition, than in the *map* condition. There were no significant age or gender differences.

5.2.2 Question Types

The mean percentage of question types *i.e information (mean 36%), confirmatory (mean 22%), confirmatory assumption (mean 42%)*, across condition and age are presented in figure 5.1.

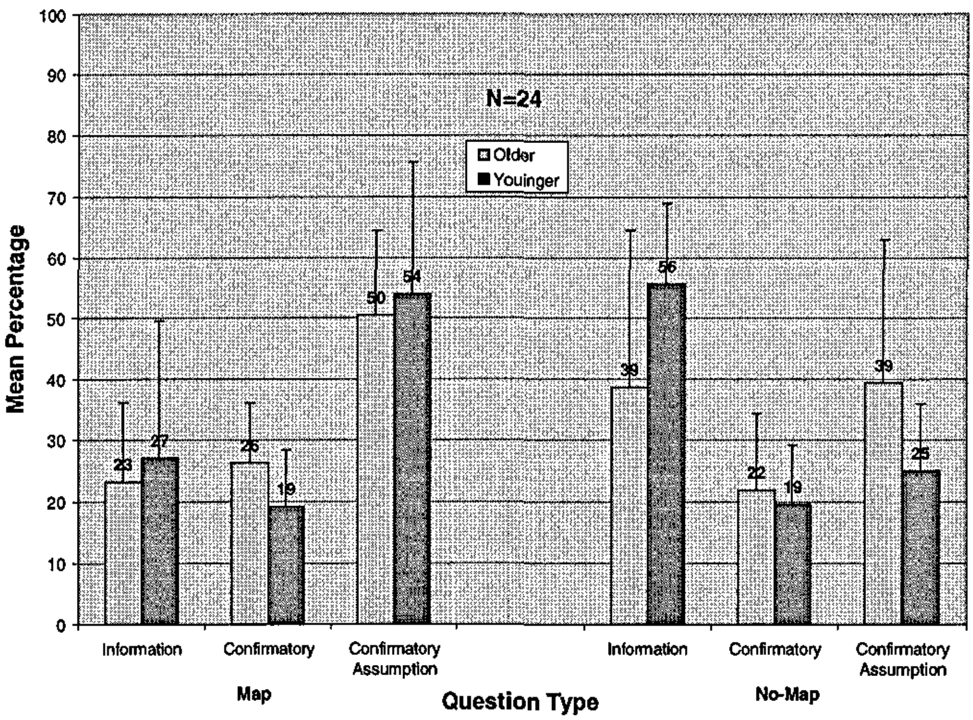


Figure 5.1: Mean Percentage of Question Types (+1 standard deviation)

A repeated-measures ANOVA was conducted, to identify differences in the question types across condition, age and gender.

Information Questions

There was a significant main effect for condition [F(1,20)=12.126 p<.01] and a trend towards a main age effect (only just missing significance at the 5% level) [F(1,20)=4.036 p<.10]. The percentage of information questions asked was significantly higher in the *no-map* than the *map* condition, and younger drivers tended to ask a higher percentage of information questions than older drivers. There was no significant interaction between age and condition, and no significant gender differences were found.

Confirmatory Questions

There were no significant condition, age or gender differences for the percentage of confirmatory questions asked by drivers.

Confirmatory Assumption Questions

There was a significant main effect for condition [F(1,20)=12.967, p<.01]. Drivers asked a significantly higher percentage of confirmatory assumption questions in the *map* than the *no-map* condition. There was no significant difference for age or gender.

5.2.3 Errors

The mean percentage of questions related to navigational errors, across age and condition are presented in table 5.2.

Table 5.2: Mean Percentage of Errors (standard deviation)

	Map	*No-Map*
Older (N=12)	18 (10.9)	22 (19.6)
Younger (N=12)	13 (12.6)	12 (8.5)

A repeated-measures ANOVA was conducted to identify differences in navigational performance across condition age and gender. There was trend towards a main age difference [$F(1,20)=3.379$, $p<.10$]. Older drivers tended to make a higher percentage of errors than younger drivers. There was no significant difference between condition or gender.

5.2.4 Route Times

The mean times taken to travel the route, across age and condition are presented in table 5.3.

Table 5.3: Mean Route Times in Seconds (standard deviation)

	Map	*No-Map*
Older (N=12)	710 (50.6)	780 (68.2)
Younger (N=12)	739 (82.5)	758 (59.5)

A repeated measures ANOVA was conducted to identify differences in route times across condition, age and gender. There was a significant main effect for condition [$F(1,20)=6.071$, $p<.05$]. Drivers in the *map* condition drove the route in a significantly shorter time than in the *no-map* condition. There were no differences across age or gender.

5.2.5 Question Categories

The mean percentage of questions, falling into each of the high level question categories, *(i.e. direction, distance, node, landmark, path and sign),* are presented in figure 5.2.

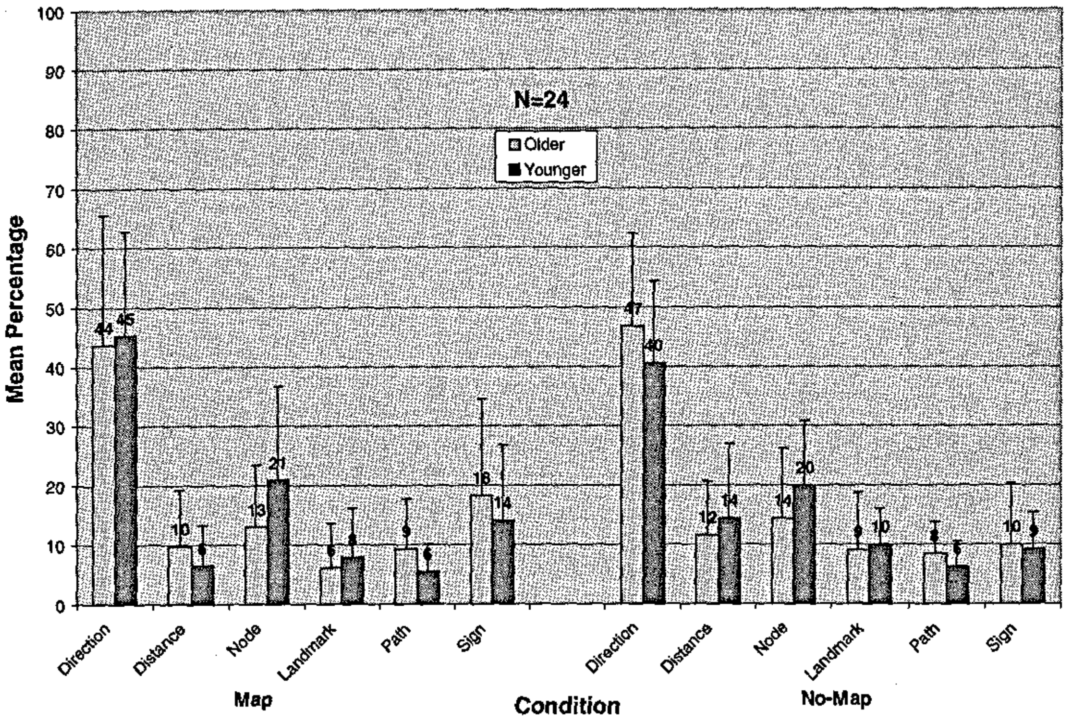


Figure 5.2: Mean Percentage of Questions in each High Level Category (+1 standard deviation)

A repeated measures ANOVA was used to identify differences in the amount of information used by drivers in each category across condition, age and gender. Correlation coefficients were also used to identify relationships between the amount of information used by drivers in each category and performance measures.

Direction Questions

There was no significant difference for condition, age or gender for the percentage of direction information sought by drivers.

Distance Questions

There was a significant main effect for condition [$F(1,20)=4.366$, $p<.05$]. Drivers asked a significantly higher percentage of distance questions in the *no-map* condition than the *map* condition. The percentage of distance questions in the *no-map* condition were also significantly correlated with the amount of errors made [$r(22)=-.499$, $p<.05$]. The more distance information sought by drivers, the fewer errors made. There were no significant differences for age or gender.

Node Questions

There was no significant difference for condition, age or gender. However the percentage of node questions in the *map* condition were significantly correlated with the time taken to complete the route [$r(22)=-.489$, $p<.05$]. The higher the percentage of node information used by drivers the shorter the time taken to complete the route.

Landmark Questions

There was no significant difference for condition, age or gender for landmark information sought by drivers.

Path Questions

There was a trend towards a main age effect [$F(1,20)=2.984$, $p<.10$]. Older drivers asked a higher percentage of path questions than younger drivers. There were no significant differences across condition or gender for the path information sought by drivers.

Sign Questions

There was a significant main effect for condition [$F(1,20)=4.396$, $p<.05$]. There were no significant differences across age or gender for the percentage of sign information sought by drivers. However the percentage of sign questions in the *map* condition were significantly correlated with the time taken to complete the route [$r(22)=.432$, $p<.05$]. The higher the percentage of sign information sought by drivers the longer the route completion time.

5.2.6 Subjective Ratings and Preferences

The participants completed subjective workload measures *(NASA R-TLX)* covering six factors *(i.e. mental demand, mental effort, physical demand, time pressure, distraction and stress level)*, giving each a rating on a continuous *scale (0 being low workload, 10 being high workload)*. The mean rating for each factor across driver age groups are presented in figure 5.3.

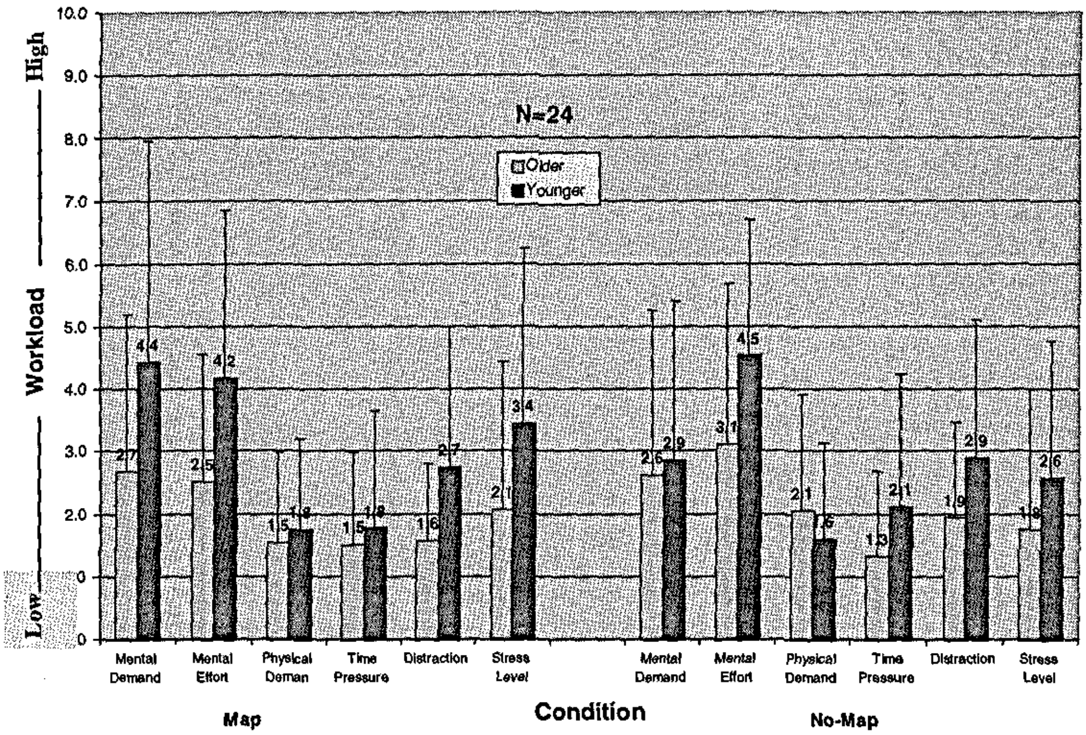


Figure 5.3: Mean Workload Ratings (+1 standard deviation)

For all of the categories in across age and condition, the subjective mean ratings fell below 5. A repeated-measures ANOVA was used to identify differences in the subjective rating by drivers in each category across condition, age and gender.

Mental Demand

There was a trend towards a main gender effect [$F(1,20)=3.085$, $p<.10$]. Female drivers tended to have a higher mental workload rating than male drivers *(means 4.0 vs 2.3)*. There were no significant age or condition differences.

Mental Effort

There was a trend towards a main age effect [$F(1,20)=3.038$, $p<.10$]. Younger drivers tended have a higher mental demand rating than older driver. There were no main effects for condition or gender.

Physical Demand

There was a main gender difference for the mean subjective rating of physical demand [$F(1,20)=8.978$, $p<.01$]. Female drivers had a higher rating of physical demand than male drivers *(means 3 vs 1).* There were no significant condition or age differences.

Time Pressure

There were no significant condition age or gender differences for the mean subjective rating of time pressure.

Distraction

There were no significant condition age or gender differences for the mean subjective rating of distraction.

Stress

There were no significant condition age or gender differences for the mean subjective rating of stress.

Overall Workload Score

The average score for each of the 6 subjective workload categories was calculated. The overall workload score across age and condition are presented in table 5.4.

Table 5.4: Mean Overall Subjective Workload Rating

	Map	*No-Map*
Older (N=12)	2.0 (2.3)	2.1 (1.8)
Younger (N=12)	3.1 (2.8)	2.8 (1.7)

There was a trend towards a main gender difference for the overall workload score [$F(1,20)=3.064$, $p<.10$]. Female drivers tended to have a higher mean overall workload score than male drivers (*means 3.1 vs 1.9*). There were no significant differences for condition or age. For overall workload was low for most drivers in both conditions.

Condition Preference

Drivers were asked to indicate which condition they preferred (i.e. having a map prior to driving, or having no-map prior to driving) when performing the navigation task.

The percentage of drivers preferring each condition, across age, are presented in table 5.5.

Table 5.5: Percentage of Drivers Preference for Condition

	Map	*No-Map*	*No Preference*
Older (N=12)	25	33	42
Younger (N=12)	25	67	8

For older drivers, most had no preference of condition, and a higher percentage preferring the no-map condition. For younger drivers, most had a preference for the no-map condition.

5.3 Question Content and Timing

This section provides the results of the detailed analysis of the question content and timing across age and gender. The questions were merged across conditions, and so condition was no longer a factor. This was done to increase the power of the analysis. On preliminary analysis of the data there were very few differences between condition in the content and timing of the questions (e.g. the type and timing of direction questions were the same in both conditions, it was only the amount of information used which changed). Any differences caused by condition will be highlighted in the discussion.

5.3.1 Direction Questions

Direction questions were used by all drivers, and was the most popular type of information sought *(mean 44%)*. This section analyses the content and timing of these questions.

Content of Direction Questions

The direction questions were grouped into three category elements: *ego-centred (mean 93%), local (mean 6%), and global (mean 1%)*. The mean percentage of questions falling into each category element, across age, are presented in figure 5.4.

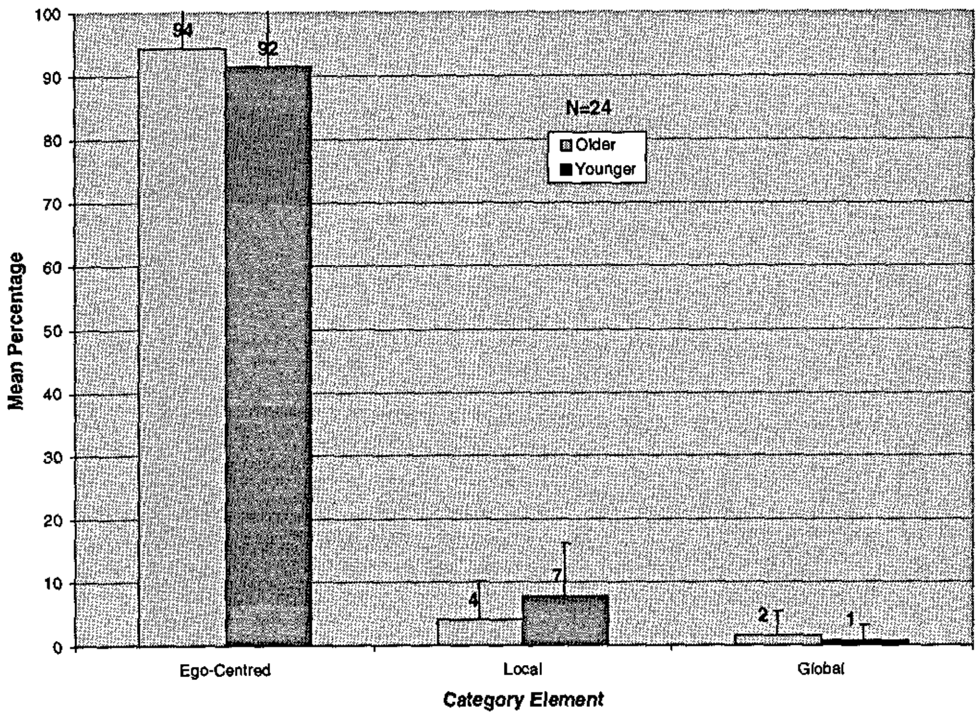


Figure 5.4: Mean Percentage of Direction Question Elements (+1 standard deviation)

A univariate ANOVA was conducted to identify any differences across age and gender. There was no significant difference for age or gender. Nearly all of the directional questions referred to ego-centred (e.g. left-right) directional information.

The reference of each of the direction questions was identified (e.g whether the direction question was in reference to the next junction, or a junction further ahead). The combination of each of the direction category elements and their references are presented in table 5.6. The questions are ranked in order of use for both younger and older drivers.

Table 5.6: Mean percentage of Direction Question References

Rank	Older Drivers (N=12)	%	Younger Drivers (N=12)	%
1	Ego-centred direction in reference to the next junction. (e.g. Am I turning left or right at the junction?)	87	Ego-centred direction in reference to the next junction. (e.g. Am I turning left or right at the junction?)	84
2	Ego-centred direction in reference to a manoeuvre. (e.g. Will my next turning be a left or right?)	4	Ego-centred direction in reference to a junction ahead. (e.g. Which way am I going at the junction after this roundabout?)	6
3	Local direction in reference to the next junction. (e.g. Which exit do I take at the roundabout?)	4	Local direction in reference to the next junction. (e.g. Which exit do I take at the roundabout?)	4
4	Ego-centred direction in reference to a junction ahead. (e.g. Which way am I going at the junction after this roundabout?)	3	Local direction in reference to junction ahead. (e.g. When I get to the roundabout after this junction which exit will I need?)	3
5	Global direction in reference to the destination. (e.g. Is Derby (destination area) north or South of here?)	2	Ego-centred direction in reference to a manoeuvre. (e.g. Will my next turning be a left or right?)	2
6	Local direction in reference to junction ahead. (e.g. When I get to the roundabout after this junction which exit will I need?)	0	Global direction in reference to the destination. (e.g. Is Derby (destination area) north or South of here?)	1

There were 5 different combinations of question used by older drivers and 6 by younger drivers. The most popular combination by far, for both driver age groups was ego-centred directional information in reference to the next junction. All of the other combinations of directional questions were comparatively unused.

Timing of Direction Questions

The times, at which direction questions were asked with respect to junctions, were categorised into two groups*: those asked on the approach to a junction (mean 80%), and those asked on departure from a junction (mean 20%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.5.

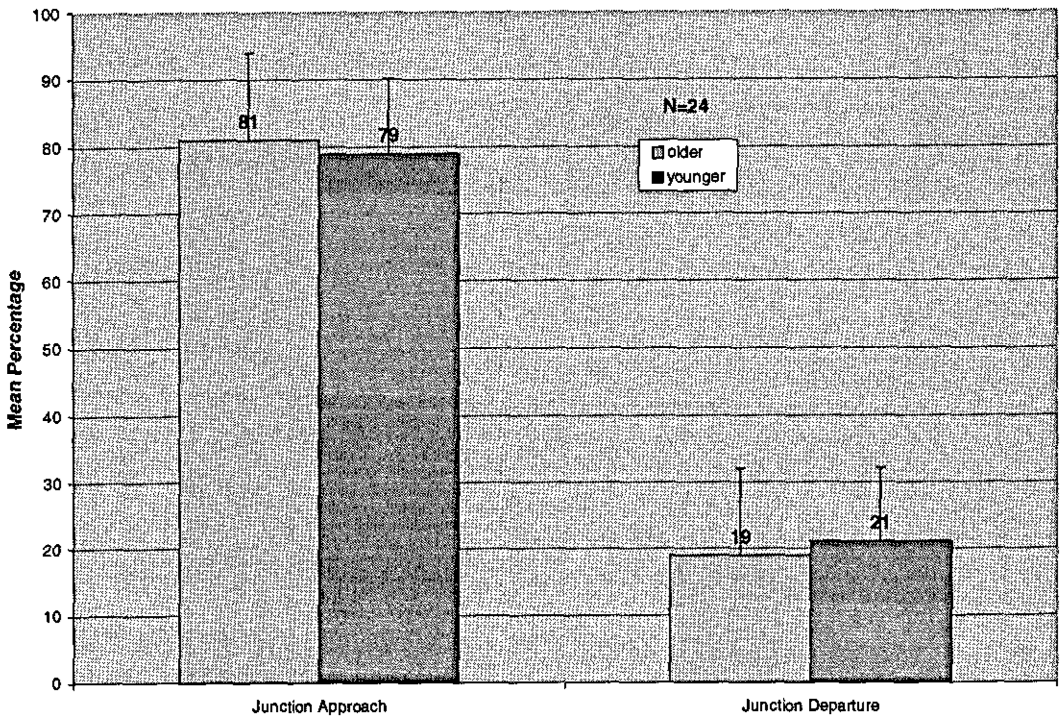


Figure 5.5: Mean Percentage of Direction Question Timings (+1 standard deviation)

A one-sample t-test revealed a significant difference in the percentage of questions asked on junction approach as compared to junction departure [$t(23)=12.331$, $p<.01$]. Significantly more direction questions were asked on the junction approach than junction departure. A univariate ANOVA was conducted to identify differences across age and gender. There were no significant differences for age or gender.

The mean percentage of direction questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.6.

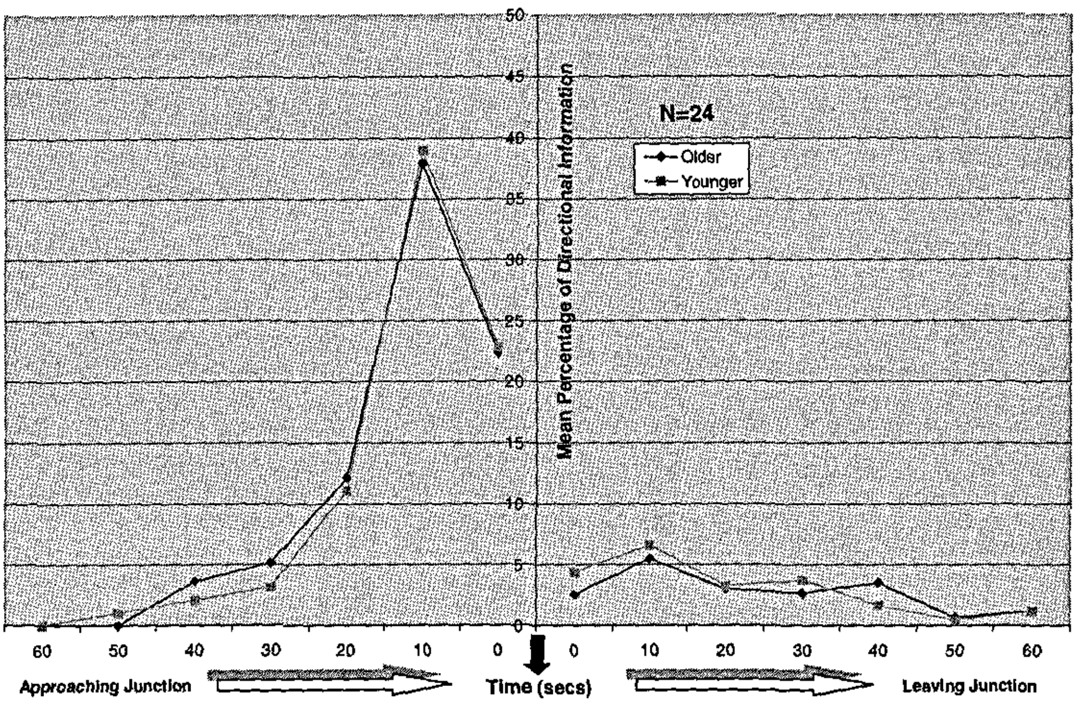


Figure 5.6: Mean Percentage of Direction Information over Time

The pattern of directional questions for older and younger drivers, over time was almost identical. On the junction approach there was a sharp increase in direction questions, for both driver age groups, at approximately 20 seconds prior to reaching the junction, peaking at approximately 10 seconds. On junction departure there was only a small amount of direction questions asked, for both driver age groups, peaking at approximately10 seconds after leaving the junction before trailing off.

5.3.2 Distance Questions

19 of the 24 drivers made use of distance information *(3 older drivers and 2 younger drivers did not use any distance information*). Distance information was the third equal most popular information type sought by drivers *(mean 12%)*. This section details the content and timing of these distance questions.

Content of Distance Questions

The distance questions were grouped into three categories: *absolute (mean 40%), cost-based (mean 50%) and relative (mean 10%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.7.

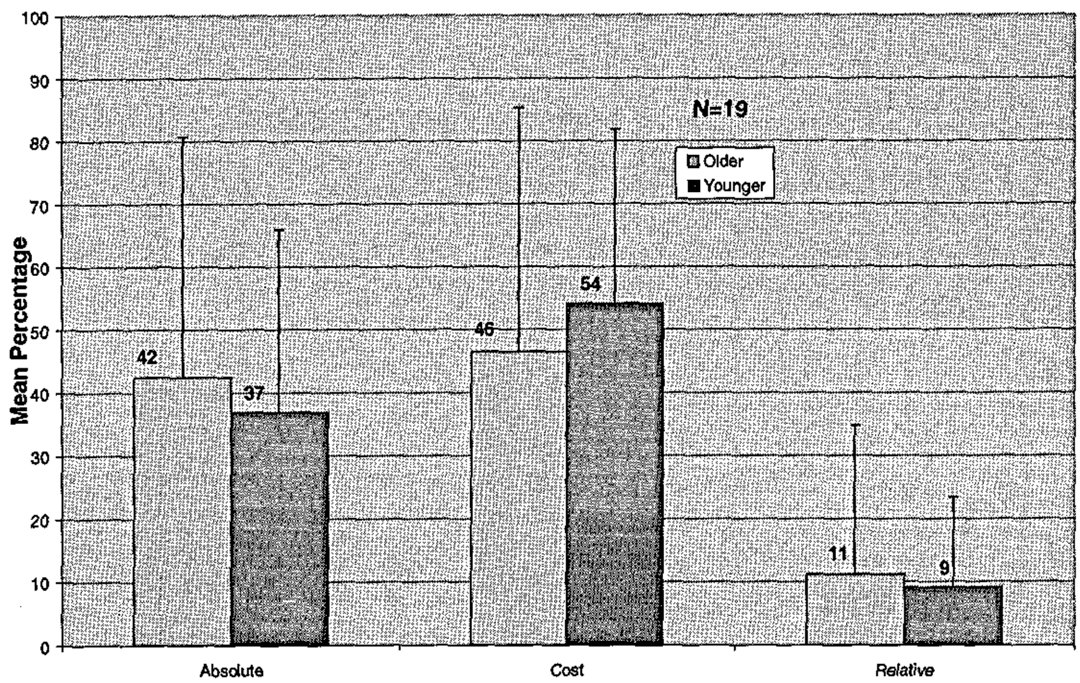


Figure 5.7: Distance Question Information Element (+1 standard deviation)

A univariate *ANOVA* were conducted for each of the distance information elements to identify differences across age and gender. There was trend towards a gender difference for absolute distances [$F(1,15)=3.378$, $p<.10$]. Male drivers tended to more *absolute* distance questions than female drivers *(means 52% vs 25%).* There was also a significant gender difference for cost-based distances [$F(1,15)=4.936$, $p<.05$]. Female drivers asked significantly more cost-based distance questions *(means 65% vs 35%).* There were no age differences for any of the information elements.

The reference of each of the distance questions was identified (e.g whether the distance was in reference to the destination or a manoeuvre). The combination of each of the distance category elements and their references are presented in table 5.7. The questions are ranked in order of use for both younger and older drivers.

Table 5.7: Mean percentage of Distance Question References

Rank	Older Drivers (N=9)	%	Younger Drivers (N=10)	%
1	Cost-based distance in reference to the destination. (e.g. How long does it take to reach the destination?)	*28*	Cost-based distance in reference to the current path. (e.g. Am I staying on this road for a while?)	36
2	Cost-based distance in reference to the current path. (e.g. Am I staying on this road for a while?)	*27*	Absolute distance in reference to the current path. (e.g. Am I carrying along this road for a mile or so?)	22
3	Absolute distance in reference to the destination. (e.g. How many miles is it to the destination?)	*13*	Cost-based distance in reference to the destination. (e.g. How long does it take to reach the destination?)	12
4	Absolute distance in reference to the current path. (e.g. Am I carrying along this road for a mile or so?)	*13*	Absolute distance in reference to the next junction. (e.g. How far away from the next junction are we?)	8
5	Relative distance in reference to the next junction. (e.g. Am I carrying along this road until the next junction?)	*11*	Relative distance in reference to the next junction. (e.g. Am I carrying along this road until the next junction?)	8
6	Absolute distance in reference to the next junction. (e.g. How far away from the next junction are we?)	*3*	Absolute distance in reference to the destination. (e.g. How many miles is it to the destination?)	8
7	Cost based distance in reference to the next junction. (e.g. Am I coming to another junction soon)	*3*	Absolute distance in reference to next path. (e.g. After turning how far am I driving on the next road?)	2
8	Absolute distance in reference to next path. (e.g. After turning how far am I driving on the next road?)	*3*	Cost-based distance in reference to next path. (e.g. After turning am do I keep driving for a while?)	2
9	Cost-based distance in reference to next path. (e.g. After turning am do I keep driving for a while?)	*0*	Cost based distance in reference to the next junction. (e.g. Am I coming to another junction soon)	1

There were 8 question combinations used by older drivers and 9 by younger drivers. For both driver groups a majority of the questions were in reference to the distance being travelled along the current path, or the distance to the destination. The distances category elements in each of these cases were both absolute and cost based.

Timing of Distance Questions

The times at which distance questions were asked were categorised into two groups: *those asked on the approach to a junction (mean 34%), and those asked on departure* *from a junction (mean 66%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.8.

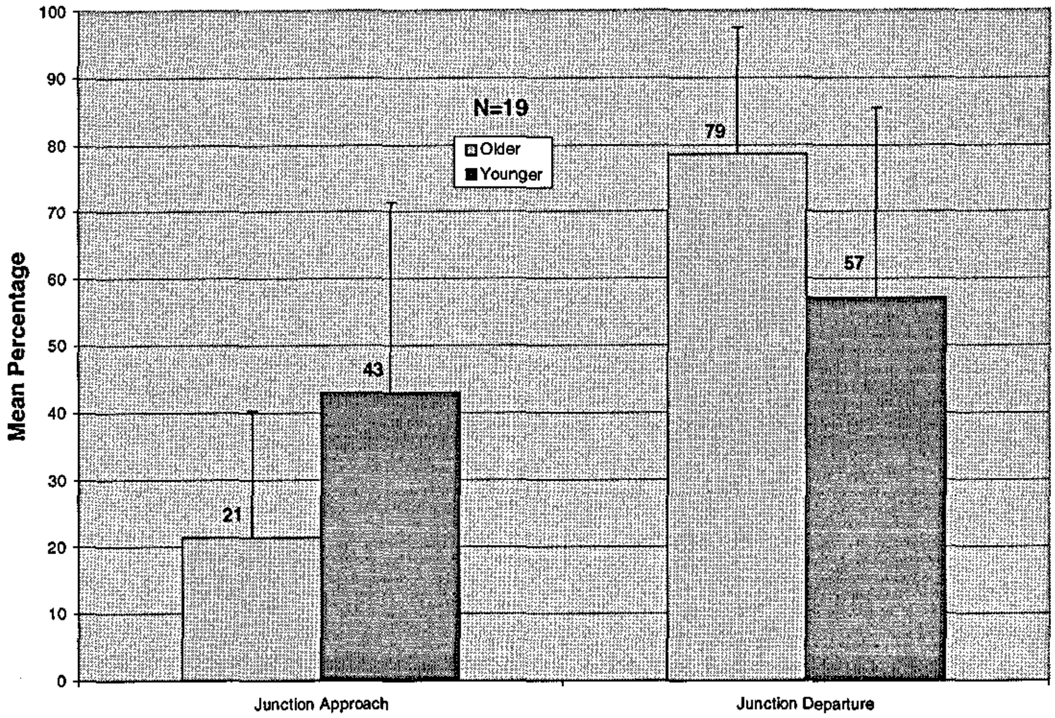


Figure 5.8: Mean Percentage of Distance Question Timings (+1 Standard Deviation)

A one-sample t-test revealed a significant difference in the percentage of questions asked on junction approach, compared to junction departure [t(19)=-2.872, p< 05]. A significantly higher percentage of questions were asked on the departure from a junction, than the approach to a junction. A univariate ANOVA was conducted to identify differences across age and gender. There was a trend towards a difference for age [F(1,17)=3.676, p<.10]. Older drivers tended to ask more distance questions on junction departure (therefore less on junction approach) than younger drivers. There were no gender differences.

The mean percentage of directional questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.9.

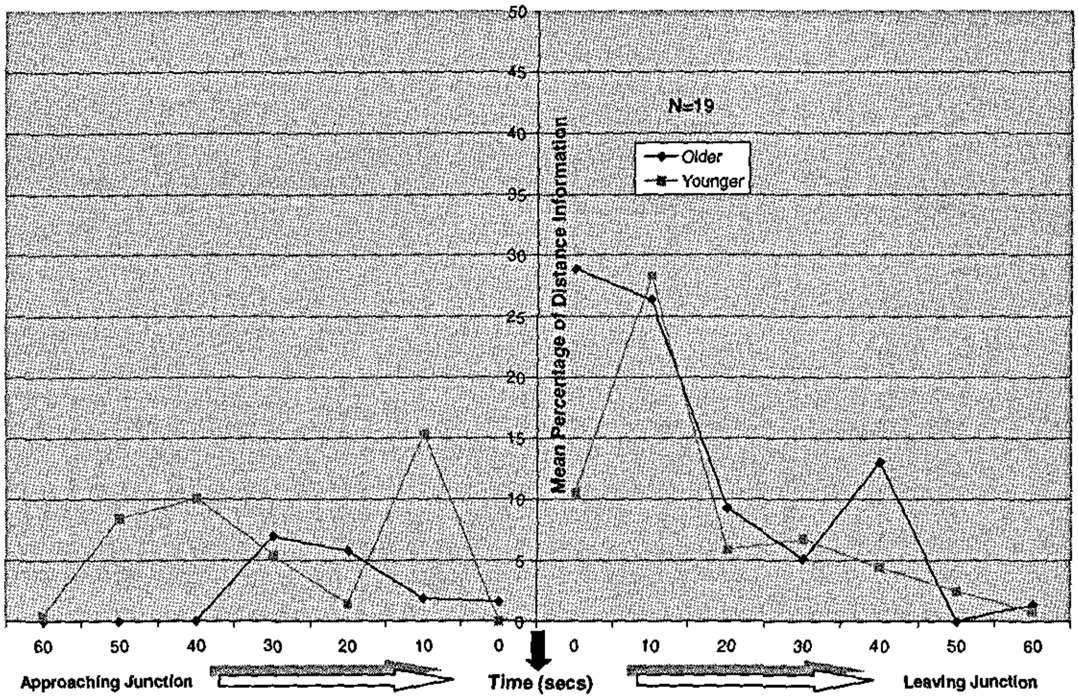


Figure 5.9: Mean Percentage of Distance Questions over Time

The pattern of distance information for the two age groups was different over time. On the junction approach younger drivers asked a higher percentage of questions 10 seconds before turning and just before turning. Question asking by older drivers here was low. On the junction departure older drivers asked the highest percentage of questions just after leaving the junction. Question asking by younger drivers here, was much lower. The highest percentage of questions on junction departure for younger drivers was at approximately 10 seconds and was equal here to older drivers.

5.3.3 Node Questions

22 of the 24 drivers made use of node *information (1 older female, and 1 younger male did not use any node information)*. This was the second most popular information sought by drivers *(mean 18%)*. This section analyses the content and timing of these questions.

Content of Node Questions

The node questions were grouped into two categories: *junction type (mean 35%), junction reference (mean 65%) and junction angle (mean 0%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.10.

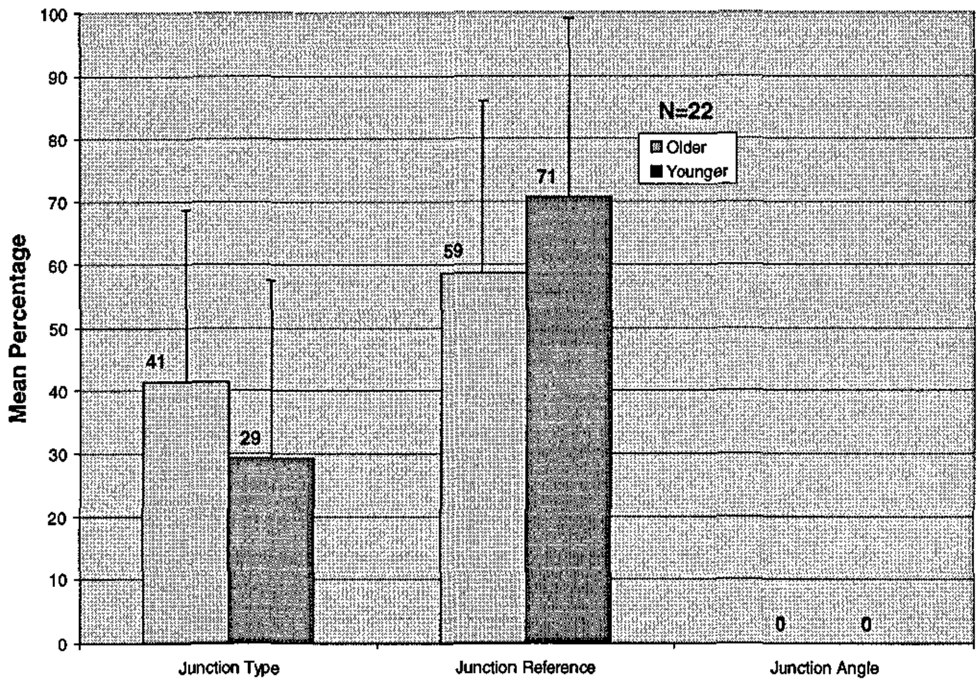


Figure 5.10: Node Category Elements (+1 standard deviation)

A univariate ANOVA was conducted to identify any differences across age and gender. There was no significant difference for age or gender. A majority of node questions were junction refernces.

The reference of each of the node questions was identified (e.g whether the node information was in reference to the next junction or a manoeuvre). The combination of each of the node category elements and their references are presented in table 5.8. The questions are ranked in order of use for both younger and older drivers.

Table 5.8: Mean Percentage of Node Question References

Rank	Older Drivers (N=11)	%	Younger Drivers (N=11)	%
1	Junction reference for the next junction. (e.g. Which way do I go *at the roundabout*?)	57	Node reference for the next junction. (e.g. Which way do I go *at the roundabout*?)	67
2	Junction type in reference to a manoeuvre. (e.g. What type of junction is it that I need to turn at?)	26	Junction type in reference to a manoeuvre. (e.g. What type of junction is it that I need to turn at?)	18
3	Junction type in reference to next junction. (e.g. What type of junction is it that I come to next?)	15	Junction type in reference to next junction. (e.g. What type of junction is it that I come to next?)	10
4	Junction reference for a junction ahead. (e.g. Which way do I go *at the roundabout, after this junction*?)	2	Junction reference for a junction ahead. (e.g. Which way do I go *at the roundabout, after this junction*?)	4
5	Junction type in reference to a junction ahead. (e.g. What type of junction do I come to after this turning?)	0	Junction type in reference to a junction ahead. (e.g. What type of junction do I come to after this turning?)	1

There were 4 different question combinations asked by older drivers and 5 by younger drivers. A majority of the questions were node references being used in conjunction with direction questions. The other main questions were in relation to the junction type that the driver would encounter either at the next junction or next manoeuvre.

Timing of Node Questions

The times at which node questions were asked were categorised into two groups: *those asked on the approach to a junction (mean 70%), and those asked on departure from a junction(mean 30%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.11.

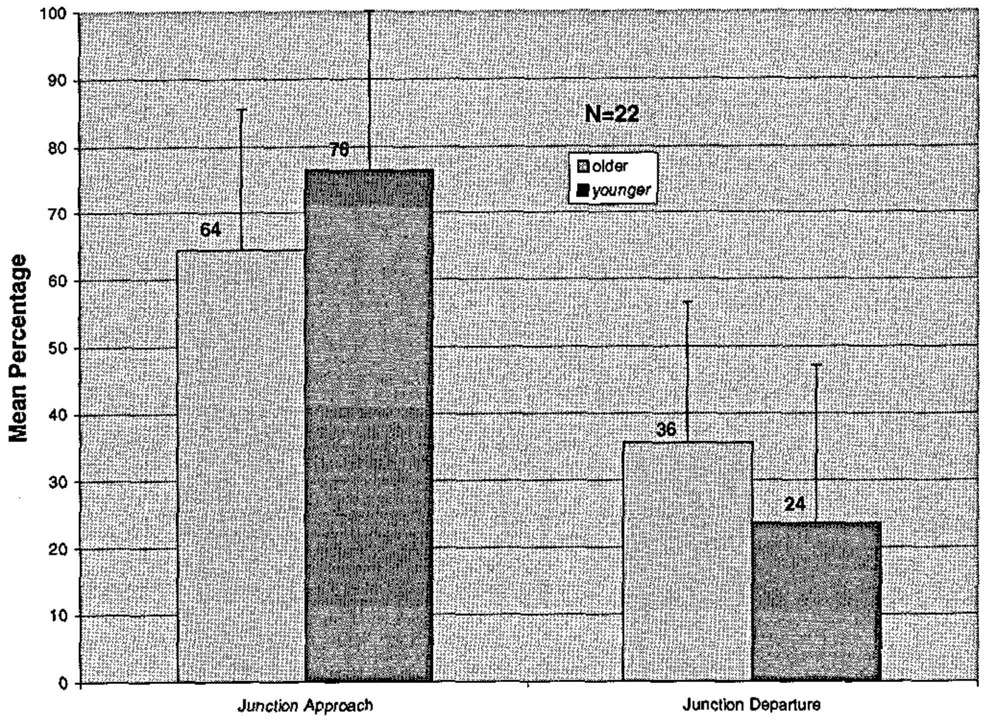


Figure 5.11: Mean Percentage of Node Question Timings (+1 standard deviation)

A one-sample t-test revealed a significant difference in the percentage of questions asked on junction approach as compared to junction departure [$t(23)=4.243$, $p<.001$]. A significantly higher percentage of questions were asked on approach to the junction, than departure from the junction. A univariate ANOVA conducted to identify differences across age and gender. There were no significant differences for age or gender.

The mean percentage of node questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.12.

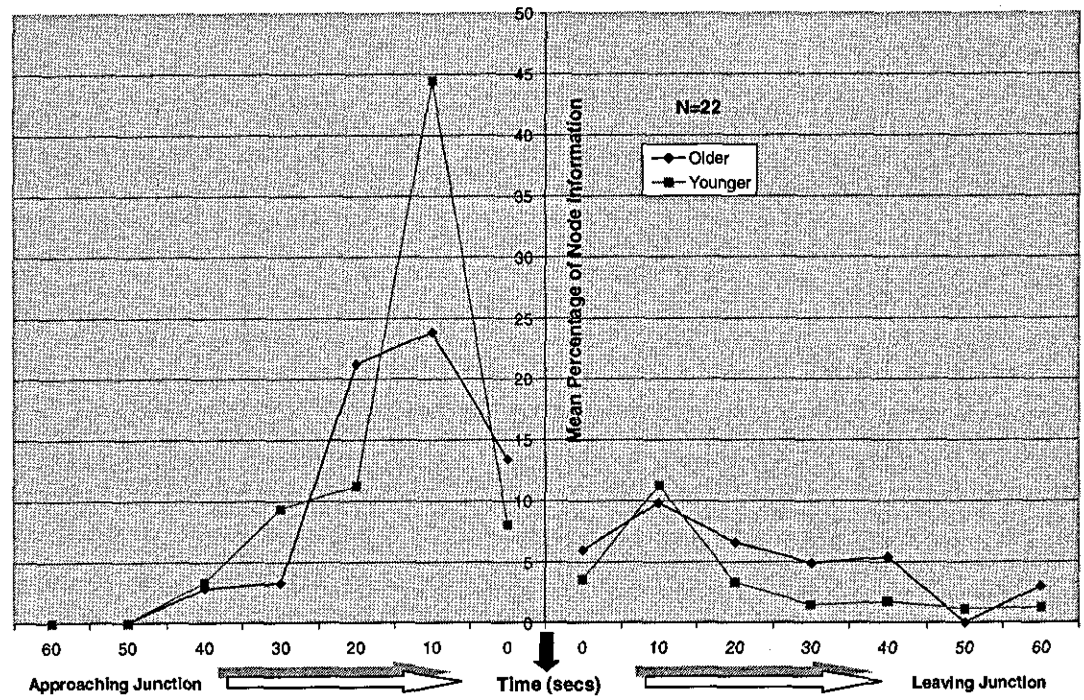


Figure 5.12: Mean Percentage of Node Questions over Time

The pattern of node information over time was different for the two age groups. The main difference occurred on the junction approach. A majority of node questions occurred at 10 seconds for both driver groups but the peak here was a lot higher for younger drivers. For older drivers the questions were spread more evenly from 20 seconds down to reaching the junction. On junction departure question asking by both age groups was low but fairly steady over the 40 seconds after leaving the junction.

5.3.4 Landmark Questions

20 of the 24 drivers made use of landmark information *(1 older male, 2 older female and 1 younger female did not use any landmark information).* Landmark information was the fifth most popular information type sought by drivers *(mean 9%)* This section details the content and timing of the landmark questions.

Content of Landmark Questions

The landmark questions were grouped into four categories: *landmark name (mean 26%), landmark descriptor (mean 9%), landmark locator (mean 24%) and landmark* *reference (mean 41%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.13.

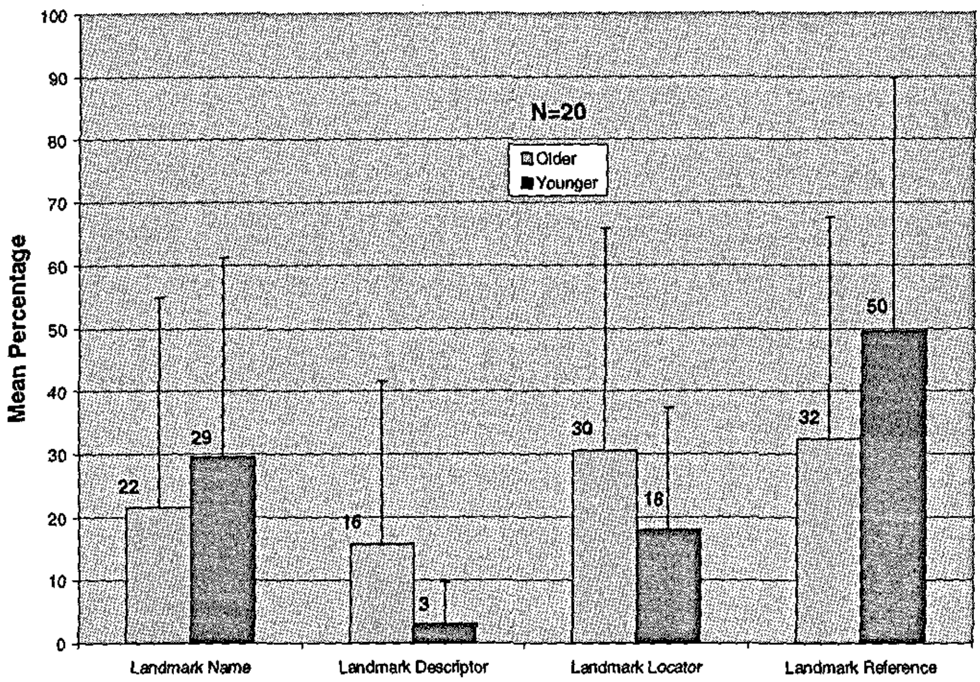


Figure 5.13: Mean Percentage of Landmark Category Elements (+1 standard deviation)

A univariate ANOVA was conducted to identify differences across age and gender. There was no significant difference across age or gender. A majority of the questions were landmark references.

The reference of each of the landmark questions was identified (e.g whether the landmark question was in reference to the destination or a manoeuvre). The combination of each of the landmark category elements and their references are presented in table 5.9. The questions are ranked in order of use for both younger and older drivers.

Table 5.9: Mean percentage of Landmark Question References

Rank	Older Drivers (N=9)	%	Younger Drivers (N=11)	%
1	Landmark reference for the next junction. (e.g. Which way do I go *at the traffic lights*?)	32	Landmark reference for the next junction. (e.g. Which way do I go *at the traffic lights*?)	50
2	Landmark locator in reference to the destination. (e.g. Which side of the road is the cinema on?)	30	Landmark Name in reference to a manoeuvre. (e.g. Are there any obvious signs of this next left turn?)	27
3	Landmark Name in reference to a manoeuvre. (e.g. Are there any obvious signs of this next left turn?)	17	Landmark locator in reference to the destination. (e.g. Which side of the road is the cinema on?)	17
4	Landmark Descriptor in reference to the destination. (e.g. What's the building like, the cinema, is it a modern building?)	16	Landmark name in reference to the destination. (e.g. Is there anything near the destination I should be looking out for, like a MacDonalds?)	4
5	*Landmark name in reference to the destination.* (e.g. Is there anything near the destination I should be looking out for, like a MacDonalds?)	4	Landmark Descriptor in reference to the destination. (e.g. What's the building like, the cinema, is it a modern building?)	3

Both older and younger drivers used 5 different types of landmark questions. The most popular for both driver groups was landmark references being used in conjunction with direction information in reference to the next junction approaching. For older drivers the next most popular use was location information for the destination, followed by using landmark information to identify where to turn, and descriptions of the destination. For younger drivers landmarks for identifying a manoeuvre were the next most popular followed by location information for the destination. Descriptive information in reference to the destination was not much used by younger drivers.

The mean percentages of each type landmark referred to by drivers are presented in table 5.10, ranked in order of popularity.

Table 5.10: Mean percentage of Landmarks Used

	Older Drivers (N=9)		*Younger Drivers (N=11)*	
Rank	*Landmark*	*%*	*Landmark*	*%*
1	Traffic Lights	*57*	Traffic Lights	*77*
2	Unspecified	*21*	Footbridge	*15*
3	Fast Food Restaurant	*11*	Unspecified	*6*
4	Foot Bridge	*11*	Petrol Garage	*3*
5	Petrol Garage	*0*	Fast Food Restaurant	*0*

Traffic lights were a major landmark for both drivers, this being the most highly used landmark by younger drivers. The *not specified* landmark refers to questions where the drivers asked the experimenter for a suggested landmark to pinpoint a particular manoeuvre.

Timing of Landmark Questions

The times at which landmark questions were asked were categorised into two groups: *those asked on the approach to a junction (mean 50%), and those asked on departure from a junction (mean 50%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.14.

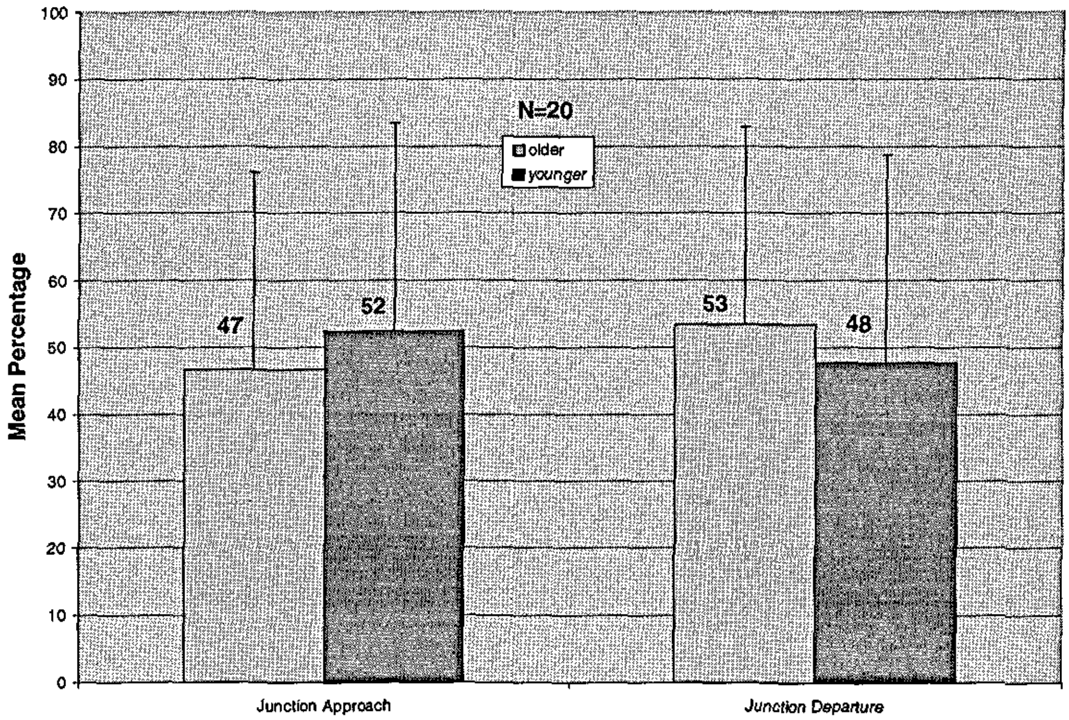


Figure 5.14: Mean Percentage of Landmark Questions Timings (+1 standard deviation)

There was no significant difference between the percentage of questions asked on junction approach and the percentage of questions asked on junction departure. There were also no significant age or gender differences.

The mean percentage of landmark questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.15.

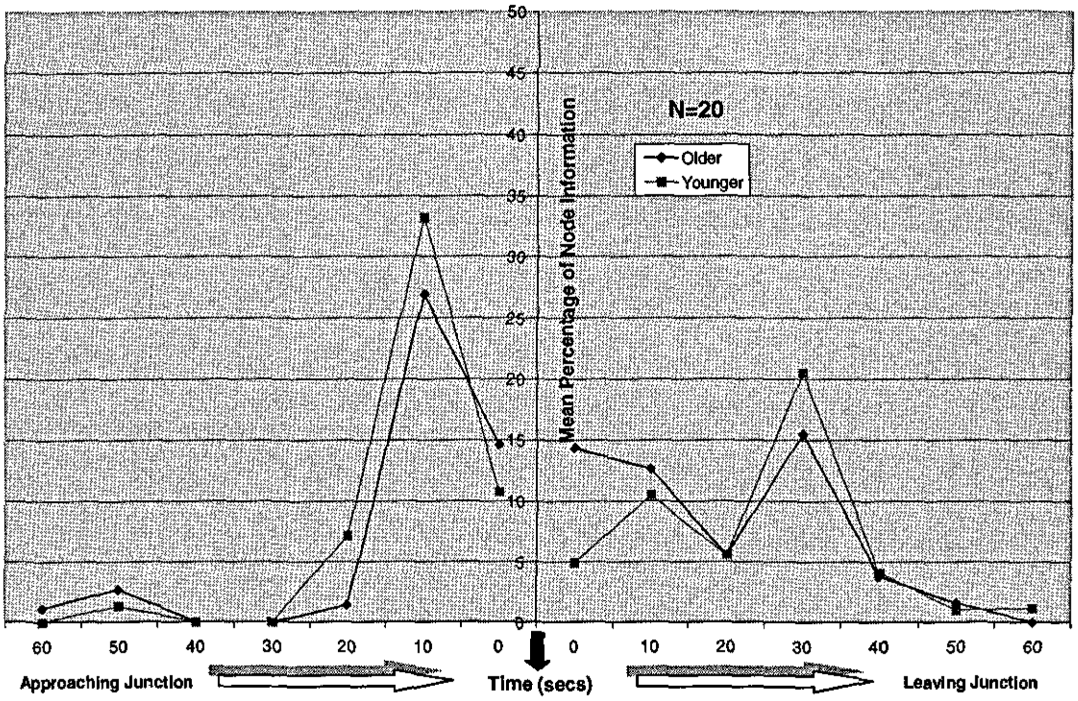


Figure 5.15: Mean Percentage of Landmark Questions over Time

The pattern of landmark information, over time, for the two age groups was very similar. On the junction approach, both driver groups had a sharp rise in landmark questions at approximately10 seconds prior to the junction. On junction departure landmark questions were asked for up to approximately 40 seconds after leaving the junction peaking at the 30 seconds mark for both driver age groups.

5.3.5 Path Questions

21 of the 24 drivers made use of path information *(1 older male, 1older female, and 1 younger male did not use any path information).* Path information was the least popular information sought by drivers *(mean 7%).* This section details the content and timing of these distance questions.

Content of Path Questions

The path questions were grouped into three categories: *path class (mean 21%), lane information (mean 15%), prior path (mean 59%), and path geometry (mean 5%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.16.

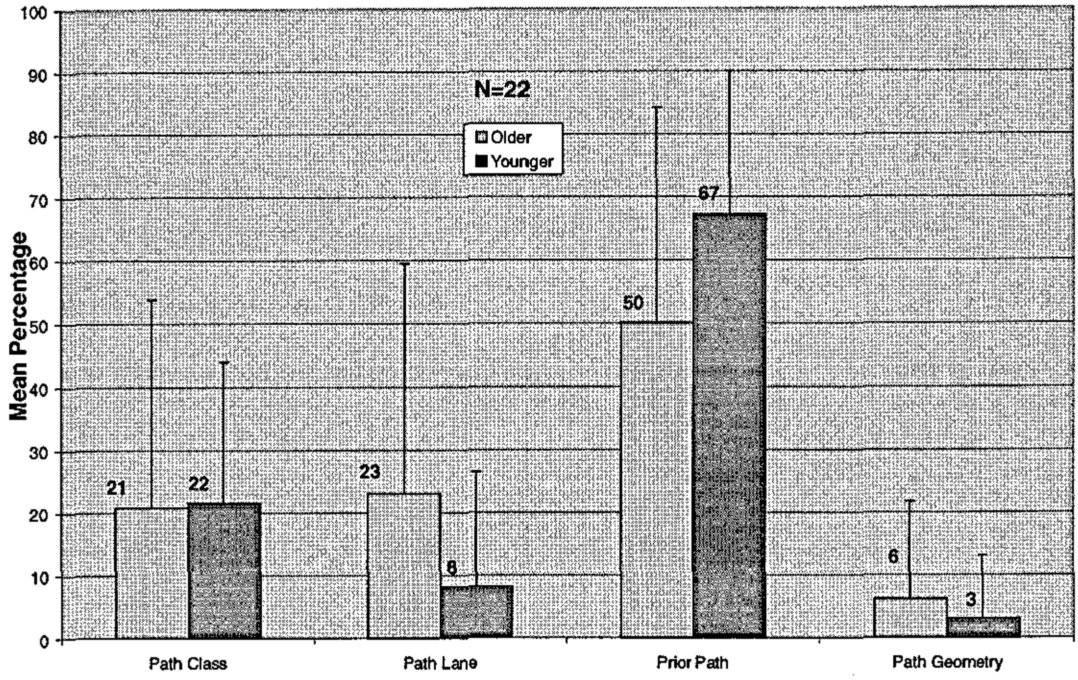


Figure 5.16: Path Questions Category Element (+1 standard deviation)

Independent-samples *t-tests* were conducted to identify differences across age and gender. There were no significant differences for age or gender. A majority of the questions were seeking prior path information (i.e. which side road to turn into). For older drivers questions seeking lane information were the next most popular, this information being relatively unused by younger drivers (though the difference was not significant). The use of path class information was similar between age groups.

The reference of each of the path questions was identified (e.g whether the path question was in reference to the current path or the next path). The combination of each of the path category elements and their references are presented in table 5.11. The questions are ranked in order of use for both younger and older drivers.

Table 5.11: Mean percentage of Path Question References

Rank	Older Drivers (N=11)		Younger Drivers (N=11)	
1	Prior Path in reference to a manoeuvre. (e.g. There's a turn off here soon, is it the next left?)	50	Prior Path in reference to a manoeuvre. (e.g. There's a turn off here soon, is it the next left?)	67
2	Lane information in reference to the next junction. (e.g. Coming up to a junction here, do I want the right or left lane?)	23	Path class in reference to next path. (e.g. Am I turning onto a main road next?)	9
3	Path class in reference to current path. (e.g. Is this staying as a rural road?)	10	Lane information in reference to the next junction. (e.g. Coming up to a junction here, do I want the right or left lane?)	8
4	Path class in reference to next path. (e.g. Am I turning onto a main road next?)	6	Path class in reference to current path. (e.g. Is this staying as a rural road?)	5
5	Path Geometry in reference to the current path. (e.g. No U-bends or anything coming up?)	6	Path class in reference to the route. (e.g. Are we mainly travelling major roads)	5
6	Path class in reference to the destination. (e.g. Is the destination on a major road?)	5	Path class in reference to the destination. (e.g. Is the destination on a major road?)	3
7	Path class in reference to the route. (e.g. Are we mainly travelling major roads)	0	Path class in reference to the destination. (e.g. Is the destination on a major road?)	3

There were 6 question combinations used by older drivers and 7 by younger drivers. The most used path information was prior path in reference to a manoeuvre for both driver groups. For younger drivers none of the other question combinations had particularly high use. However for older drivers lane information in reference to the junction being approached appeared to be of importance.

Timing of Path Questions

The times at which path questions were asked were categorised into two groups: *those asked on the approach to a junction (mean 44%), and those asked on departure from a junction (mean 56%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.17.

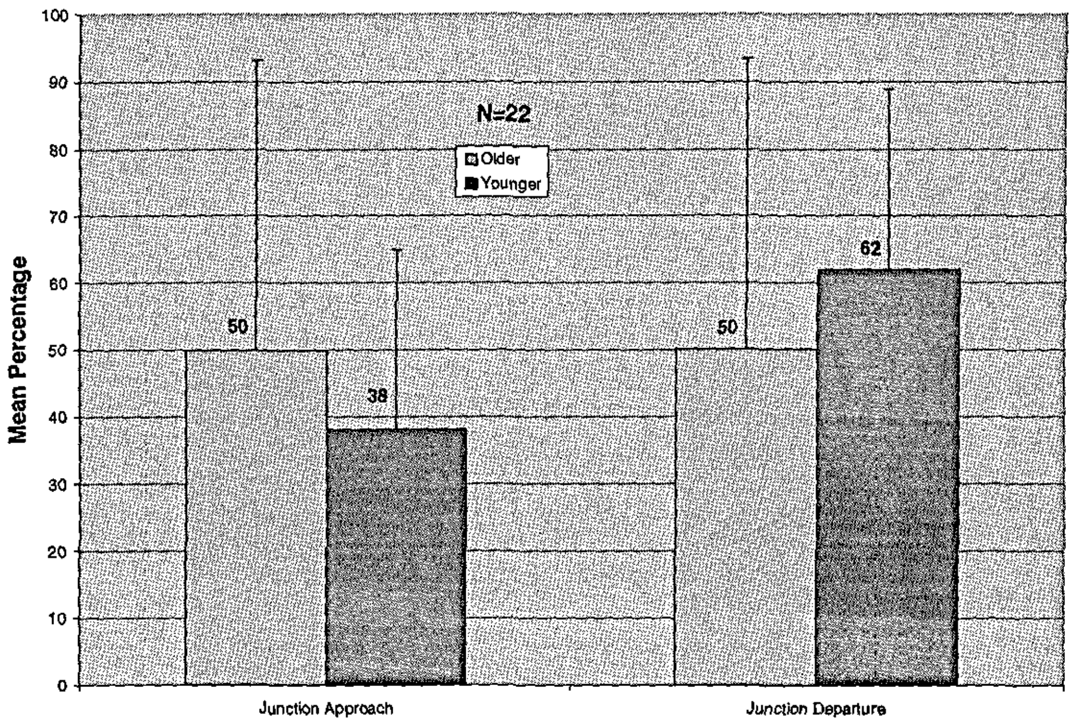


Figure 5.17: Mean Path Question Timings (+1 standard deviation)

A one-sample t-test revealed a trend towards a difference in the percentage of questions asked on junction approach, compared to junction departure. A higher percentage of questions were asked on the departure from a junction, than the approach to a junction. A univariate *ANOVA* was conducted to identify differences across age and gender. There were no differences for age or gender.

The mean percentage of path questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.18.

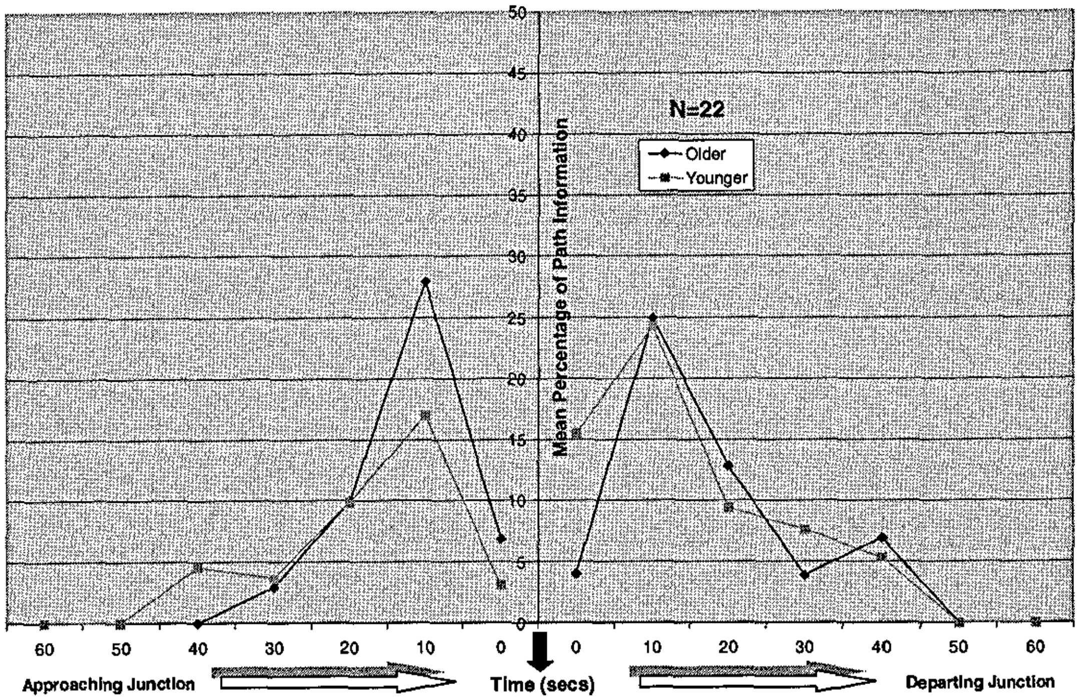


Figure 5.18: Mean Percentage of Path Questions over Time

The pattern of path information over time for the two age groups was very similar. On junction approach most of the questions were asked between the 20 seconds, and 10 seconds mark (peaking at the 10 seconds mark), for both driver age groups. On junction departure, where a majority of path questions were asked, most information was sought in the first 20 seconds (peaking at the 10 seconds mark) for both driver groups.

5.3.6 Sign Questions

23 of the drivers made use of sign information *(1 older female did not use any sign information)*. Sign information was the third equal most popular information type used *(mean 12%)*. This section details the content and timing of these sign questions.

Content of Sign Questions

The sign questions were grouped into three categories: *Place Name (mean 49%), Point of Interest (mean 23%), Road Name (mean 7%), Road Number (mean 21%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.19.

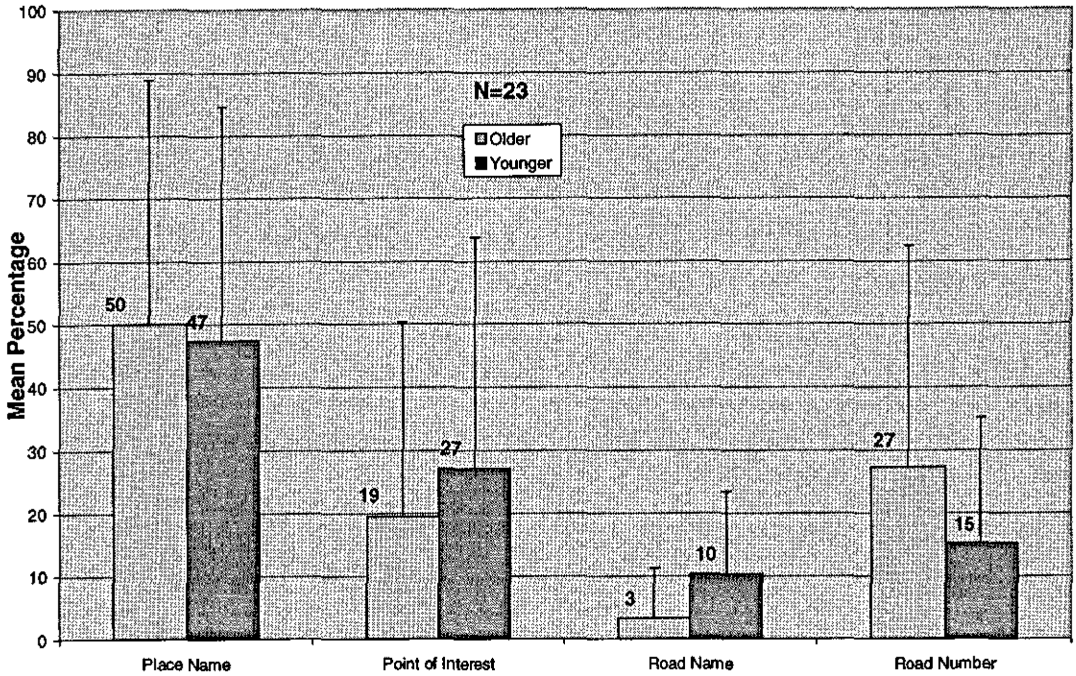


Figure 5.19: Sign Question Category Element (+1 standard deviation)

A univariate ANOVA was conducted to identify differences across age and gender. There was a trend towards a gender difference [$F(1,19)= 5.694$, $p<.05$]. Female drivers asked a significantly higher percentage of questions related to points of interest than male drivers *(means 39% vs 8%).*

The reference of each of the sign questions was identified The combination of each of the sign category elements and their reference (e.g whether the sign question was in reference to the driver's current position or the destination). References are presented in table 5.12. The questions are ranked in order of use for both younger and older drivers.

Table 5.12: Mean percentage of Sign Question References

Rank	Older Drivers (N=11)	%	Younger Drivers (N=12)	%
1	Place name in reference to driver position. (e.g. What's this place we're are in called?)	28	Point of Interest name in reference to the destination. (e.g. What's the name of the leisure park where the cinema is?)	27
2	Road/street name in reference to next path. (e.g. Was the next road called Chellaston Road?)	20	Place name in reference to the destination. (e.g What district is the destination in?)	24
3	Point of Interest name in reference to the destination. (e.g. What's the name of the leisure park where the cinema is?)	19	Place name in reference to driver position. (e.g. What's this place we're are in called?)	19
4	Place name in reference to the destination. (e.g What district is the destination in?)	17	Road/street name in reference to next path. (e.g. Was the next road called Chellaston Road?)	15
5	Road name in reference to the current path. (e.g. This is Chellaston road is it?)	7	Road Number in reference to the next path. (e.g. And it's the A5111 I wand next?)	10
6	Place Name in reference to the next junction. (e.g. I turn towards Nottingham?)	5	Place Name in reference to the next junction. (e.g. I turn towards Nottingham?)	4
7	Road Number in reference to the next path. (e.g. And it's the A5111 I wand next?)	3	Road name in reference to the current path. (e.g. This is Chellaston road is it?)	0

There were 7 question combinations used by older drivers and 6 by younger drivers. The most used questions type for older drivers was a place name in reference to the driver position followed by road/street names in reference to the next path. The most popular question combinations varied between the two driver age groups, but the top 4 for each for each driver group contained the same question combinations.

Timing of Sign Questions

The times at which sign questions were asked were categorised into two groups: *those asked on the approach to a junction (mean 64%), and those asked on departure from a junction (mean 36%).* The mean percentage of questions falling into each category, across age, are presented in figure 5.20.

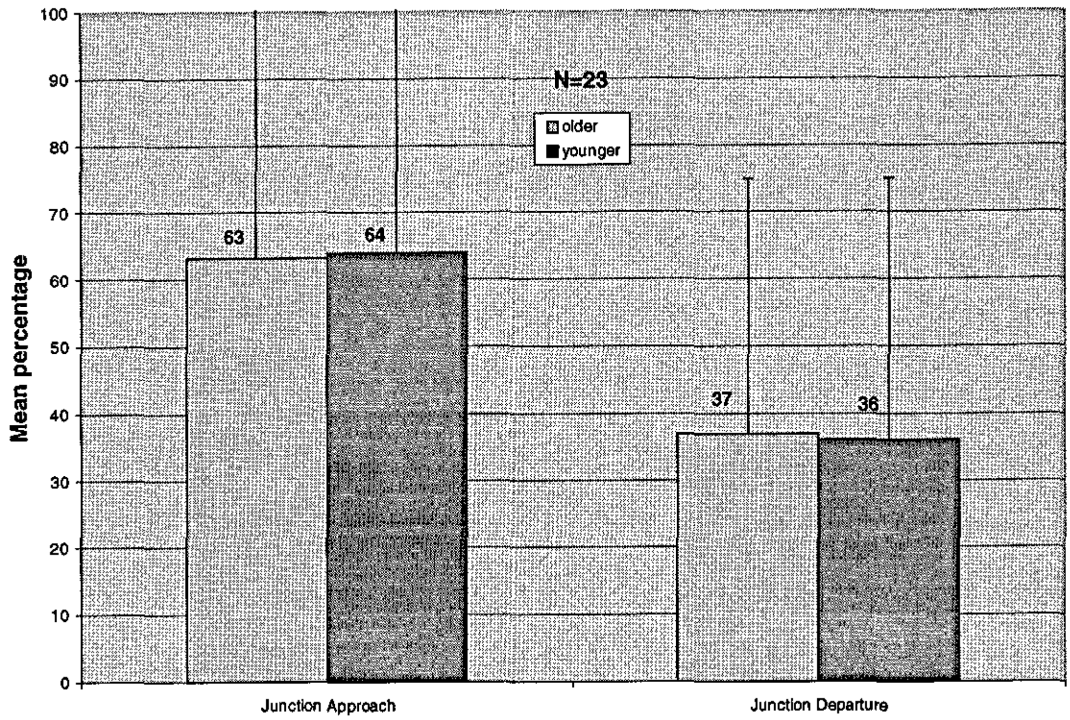


Figure 5.20: Mean Percentage of Sign Question Timings (+1 standard deviation)

There was no difference between the percentage of questions asked on junction approach and junction departure. There were also no significant differences across age or gender.

The mean percentage of sign questions asked on the junction approach, and the junction departure for each age group, were calculated over 10 second intervals. The frequency polygon is presented in figure 5.21.

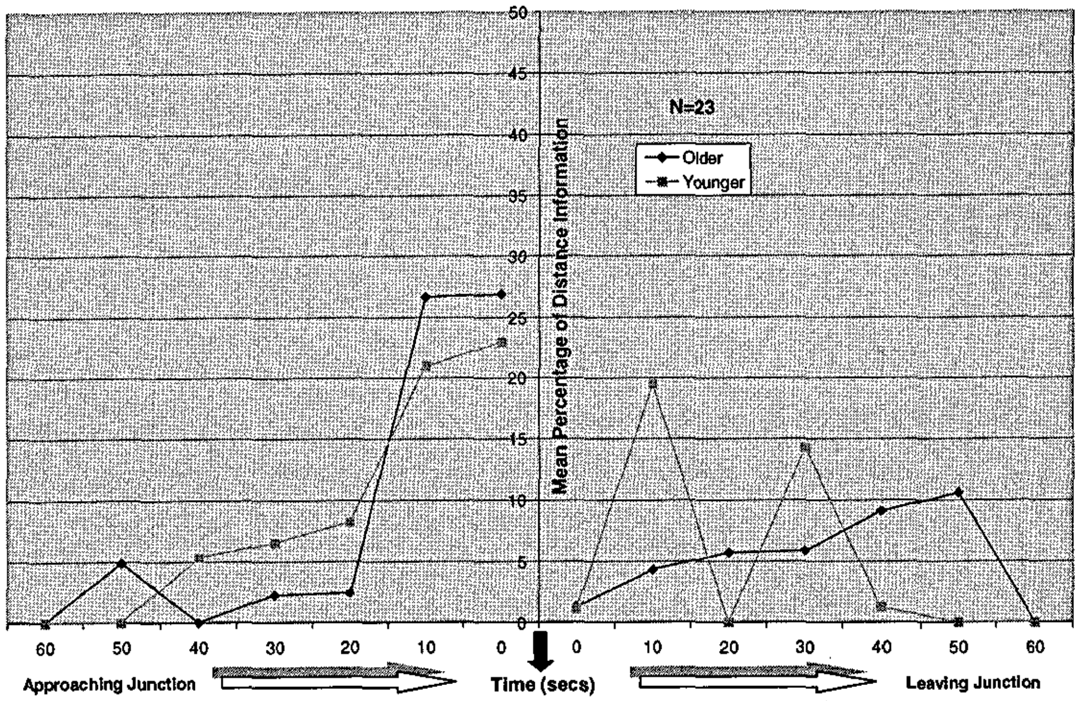


Figure 5.21: Mean Percentage of Sign Questions over Time

The pattern of sign information over time for the two age groups was very similar. On junction approach most of the questions were asked between the 10 seconds, and 0 seconds mark (peaking at the 0 seconds mark), for both driver age groups. On junction departure, there was a steady amount of sign questions up to 40 seconds after leaving the junction (peaking at 30 seconds for both driver groups).

5.4 Chapter Conclusions

This chapter as presented the results from the field trial. The driver performance showed differences in condition (map vs no map) for the number of questions asked, route times, question types, and the high level categorisation. Age differences were also found for question types and errors. The main questions asked by drivers sought information on directions, nodes, distances and signs. The detailed content analysis revealed that direction questions were mainly ego-centred and asked on junction approach. Node information was often used as a reference in combination with direction questions, and information on the junction type of the approaching junction was also sought. Distance information sought by drivers was a mixture of cost based and absolute distances, in reference to either the current path being travelled or the destination. These questions were mainly asked on junction departure. Sign information. Sign questions were mainly seeking information on the drivers current position, the location of the destination, or the name of roads. The detailed content analysis revealed only a few differences across age. One of the main findings was older drivers requirements for distance information shortly after leaving a junction.

Chapter 6: Study 1 Discussion

6.1 Chapter Summary

This chapter discusses the field trial results. The first part of the chapter covers the findings on driver performance measures, and behaviour across the two experimental conditions and age groups. The second part of the chapter discusses the results from the detailed contents analysis, timing analysis of the questions asked by drivers. The last part of the chapter discusses driver navigation strategies, and provides recommendations for a route guidance system.

6.2 Driver Performance & Behaviour

This section discusses the results of the driver performance and behaviour across the two experimental conditions (map vs no-map) and age groups.

6.2.1 Number of Questions Asked

The amount of information required by drivers was higher in the no-map condition than the map condition. This result was not unexpected, due to the overview the map provided. Drivers reported in the map condition that they would try to memorise as much as the route as possible, and therefore would require less information from the experimenter. However, none of the participants managed to drive the whole route from memory and for many, information from the experimenter would be required early on in the route. This was mainly in the form of directional information due to memory failures *(e.g. "I can't remember if it was left or right here?")*. This is consistent with Schraagan (1990) who reported that the cause of navigation errors during his field trials were down to memory failures rather than map reading abilities. The number of decision points was high enough to make memory of the whole route difficult, and so drivers still required information.

6.2.2 Question Types

In the no-map condition mainly information questions types were used. This was due to the drivers not having an overview of the route prior to driving and so would have to seek more information which otherwise could have been picked up from the map. In the map condition, confirmatory assumption questions were mainly used as the driver tried to confirm information stored in their cognitive map. In both conditions the use of confirmatory questions remained the same, these questions being used to confirm information already given by the experimenter, either because they had forgotten what they had been told or to make sure they were about to make the correct manoeuvre.

Younger drivers used a higher proportion of information questions than older drivers especially in the no-map condition, acquiring information on the route ahead more readily. This was due to a combination of older drivers using a slightly higher percentage of confirmatory questions in both conditions, and a higher use of confirmatory assumption questions in the no-map condition (though each of these individually was not significant between age groups). The higher percentage use of confirmatory assumption questions in the no-map condition for older drivers appears a strange strategy as without any prior knowledge of the route it was difficult to make too many assumptions. The driver on making an assumption of which way to go, for example, would also begin to position the car for that manoeuvre. The reasons for such a strategy is possibly because it requires less cognitive processing, as the driver tries to confirm a decision already made, and so was therefore favoured by the older drivers, due to more limited information processing capabilities. However if the assumption was wrong, it was sometimes too late to correct the manoeuvre. In the map condition, especially for older drivers, a wrong assumption greatly disorientated the driver, and led to further confusion at subsequent junctions due to conflicts between what they had seen on the map and the directions being given.

6.2.3 Errors

The condition had little effect on the errors made by the drivers. However there was a trend towards a difference between age groups. In the map condition older drivers tended to make more errors due to memory failures of the route being travelled, and so tried to confirm information from the map which was wrong, or attempted more incorrect manoeuvres. In the no-map condition older drivers asked more confirmatory assumption questions and so had a higher chance of making an error, as the assumption could easily be wrong. These two facts combined led to an overall higher error rate for older drivers.

6.2.4 Route Times

The effect on route times of having a map prior to driving was to significantly reduce the amount of time taken. This gives an indication that having the map prior to driving actually helped reduce uncertainty. Having no overview of the route meant the drivers were often uncertain of what to do or what to expect and so compensated by slowing down. Strategies also played a part here. It was observed that drivers who sought information on future events (thus compensating for the information which would have been provided by the map), appeared to drive with less uncertainty (i.e. slowing down behaviour was less common). This strategy also appeared to have some advantages to having the map preview. Much confusion was caused if the drivers expectations acquired from the map conflicted with information received from the experimenter. When no map was present the preview information was sought from the experimenter and so there was limited opportunity for conflicts to occur. Both driver age groups were affected the same by the conditions and there were no differences between the two.

6.2.5 Question Categories.

In the *no-map* condition drivers mainly sought information on directions, nodes and distances. In the *map* condition drivers also sought information on directions and nodes, but there was a significant increase in the percentage of sign information used and a significant decrease in the percentage of distance information sought. This suggests that when drivers had a map their navigation strategy shifted to using more non-spatial information such as road signs. Schraagan (1990), also reported a high incidence in the use of sign information when drivers used maps. It was reported that it was difficult for drivers to use metric knowledge (see chapter 2) derived from maps in unfamiliar environments. The increase in the use of sign information in the map condition suggests that this may have been the reason for the faster route times attained in this condition. There was indeed a significant correlation between sign information and route times in the map condition but the correlation was positive indicating that the increase in the percentage of sign information sought the longer the route time. This was because to make use of sign information drivers had to locate the sign in the environment before being able to make use of it. This indicated that the faster route times may have been due to the distance information that was being acquired from the map (therefore the driver did not require as much information from the experimenter). This information would give spatial knowledge of the route ahead, reducing uncertainty as the driver would have some idea of the immediacy of decision points. In the no-map condition the use of distance information was significantly correlated with a reduction in the number of errors made. Again having some idea of the distance to travel along roads meant that the drivers would be able to assume 'straight on' directions at many of the junctions encountered (as they would know approximately the distance they were to stay on that road). When used in conjunction with node information the driver would know approximately how far to a turn the junctions to be encountered and the type of junction to turn at. Indeed node information, in the map condition was significantly correlated with faster route times.

Both path and landmark information were used relatively little by the drivers. For path information there was a trend towards an age difference, older drivers using more path information than younger drivers. This appeared to be due to a higher percentage of lane information being sought by older drivers, of which for younger drivers remained relatively unused. The low use of landmark information is in contrast to many of the previous studies in the literature review (e.g. Alm 1990; Daimon et al 1997; Burnett 1998). This is due to the experiment being in real-time rather than planning a route to drive. Reasons for the relatively little use of landmark information will be discussed further later on.

Overall the information used in each of the conditions and across age groups, was relatively similar. Although there were differences with sign and distance information in the map condition, once memory failures occurred drivers tended to revert to the strategies employed in the no-map condition. Apart from path information, there were no trends or significant differences in the use of the different information categories across age groups.

6.2.6 Subjective Workload Rating

This is a standard workload measurement and is performed in each experimental condition, allowing the participant to indicate their perceived workload for the task completed. Even though this has some disadvantages (e.g. the participant assessing what they have just done rather than indicating how difficult the task is whilst it is being performed), it has been validated and widely used. Also applying the test whilst the person is performing the task may itself induce extra workload.

The mean perceived workload ratings for each of the six factors was fairly low. There were no significant differences between condition for the workload across each of the six factors. This appeared to be due to the fact that the participants could ask questions in both of the conditions. As it was difficult to remember all of the route from the map the participant was then switching to asking questions as in the no-map condition. This would therefore lead to similar workloads in both conditions. However there were some age and gender differences.

Younger male drivers reported a higher mental effort than older drivers. It is unclear why this trend emerged as it would seem reasonable to assume the trend the other way, given previous research on the difficulty of the navigation task for older drivers (e.g. Sixsmith 1990; Burns 1997; AA 1988). It is possible that younger drivers felt more reluctant to ask for information from the experimenter (especially in the map condition), thus making the task more demanding. There was evidence of this reported by younger drivers when indicating condition preferences (see section 6.2.7).

The perceived physical demand when performing the tasks was higher for females than males. Even though the physical rating for each of the gender groups was low, there was a significant difference. This is probably more to do with the design of the vehicle, in relation of car controls (e.g. ease of operation, location), due to differences in size and strength between males and females.

There were no differences between condition, age or gender for time pressure, distraction and stress, the perceived workload for each of these being relatively low. However the overall workload of the six factors combined showed that overall female drivers had a higher perceived workload than male drivers. Streff & Wallace (1993), found that female drivers reported more problems with navigating in an unfamiliar areas. This suggests that the perceived workload when performing the task would be higher, as found in the present study.

6.2.7 Condition Preferences

A majority of the older drivers had no preference for either of the two conditions under which the navigation task was performed. The map was the least preferred of the two conditions. The map for younger drivers was also the least preferred method of navigation, with a vast majority preferring the no-map condition. One of the reported problems with the map was that drivers became confused, when what they were told to do did not meet their expectations, e.g. thinking they were going left and being told to go straight on. This greatly disorientated the drivers. Also many participants (especially younger drivers) felt they were being tested in the map condition and so tried to memorise what they could. It was made clear to the drivers that their map reading abilities and recall were not under test and the map was provided for any information they wished to use from it. This did not however compound any of the findings. In a navigation situation with a map it seems reasonable to assume that a person would try to learn what they could about the route. Also the route made it very difficult to memorise it all from a map and so the drivers eventually had to ask the experimenter for information.

Many of the older drivers reported no preference as they simply asked questions in both conditions. Those reporting the no-map condition as their preference found it less demanding just to rely on the experimenter for information as decision points were encountered, as often what was represented on the map did not correspond well to the environment being travelled. The main reason for the preference of the map condition by drivers was that it provided a good overview of the route prior to driving.

6.3 Information Content and Timing

This section provides discussion on the information content and timing of the questions asked by the drivers.

6.3.1 Direction Questions

Content of Direction Questions

Nearly all of the direction questions asked were ego-centred *(e.g. "Do I go left or right?").* This finding is consistent with those of previous research whether it be questionnaire studies of perceived usefulness (e.g. Burns 1997; Burnett 1998), actual use in lab trials (Alm 1990; Burnett 1998), or actual use in field trials (Daimon et al 1997). There were no differences across age or gender for the different types of directional information sought by drivers.

The use of ego-centred directions appears to be the mainstay of navigation and is therefore a crucial information element for any route guidance system. The terminology (e.g. left-right), is natural to most drivers and so produces an easily understandable information element. The use of ego-centred direction questions, however, is not without its' problems. Two people (1 older female, 1 younger female) reported having difficulty distinguishing between left and right, and would often point to confirm the direction. Clearly a navigation system based on ego-centred directions could therefore cause problems for such drivers, though to some degree this could be overcome through the use of replicating the pointing action (e.g. using arrows).

The most common reference of ego-centred directional questions was the next junction being approached. Very few drivers asked for information on junctions further ahead than the one being approached. Drivers would simply obtain ego-centred directional information (i.e. right/left/straight-on) for each junction they encountered. In this way the driver was using directional information to break down the overall goal of reaching the destination, into sub-goals. That is at any point time the driver set as their current sub-goal negotiating the next junction. These findings differ in two ways from the study by Daimon et al (1997) which is the only other study which formally considered question references. Firstly they reported that drivers would often direct their attention to a junction further ahead when waiting at traffic lights or when they had spare time. This happened only occasionally in the present study. Secondly Daimon et al (1997) found drivers formed sub-goals, directing their attention to the next manoeuvre (i.e. the next turn off the current path they were travelling). This therefore wouldn't necessarily be the next junction, as continuing straight-on at a junction was not considered a manoeuvre. It was reported by Daimon et al (1997), that junctions in between the manoeuvres were of relatively little interest to the driver. Drivers in the present study only occasionally used this method. It is unclear why these differences occurred. The study by Daimon et al (1997) only employed the use of 5 participants which is relatively low. Also in the present study if drivers knew they were maintaining their current path for a period of time they would nearly always seek confirmation of the direction required (i.e straight-on) at junctions encountered within this time. In this way they may have been working from manoeuvre to manoeuvre but in contrast to the study by Daimon et al (1997) interim junctions were not of little interest.

The use of local direction questions was occasionally used in place of ego-centred, when negotiating roundabouts *(e.g. "Do I take the 2nd exit?")*. The low used of local direction information was probably due to the types of roundabouts encountered, rather than the usefulness of the information. All of the roundabouts encountered had a maximum of 4 exits and so it was easy to attribute a left/ right/ straight-on tag to them. If larger roundabouts with more exits had been encountered this may have changed the situation as there would have been a number of exits to the left and right, making ego-centred directional information difficult to use. Indeed Daimon et al (1997) observed that participants felt uneasy, and their driving performance deteriorated, when they came across junctions involving 5 exits. Local information may have been preferable in such situations though Burnett (1998), highlights that for larger roundabouts it may not be possible to see the exits from a distance and so the local reference can be lost. This situation reflects the uniqueness of the roundabout problem due to their varying size and complexity, and the need for further research (Burnett 1998).

As with ego-centred direction questions, the most common reference of the local-direction questions was the next junction. Indeed this was the only reference for older drivers whereas younger drivers did also reference junctions further ahead than the one being approached. As local directional questions substituted ego-centred questions the references remained very much the same.

Only three drivers (2 older female, 1 younger female), made use of global references. This low use of global direction is consistent with the findings of previous research (e.g. Alm 1990; Burnett 1998; Schraagan 1993). In all cases the question was in reference to the global direction of the destination *(e.g. "Is Derby north of here?")*, and so the information was not deemed useful for making manoeuvres. The low use of global instructions appeared to be for a number of reasons. Firstly in the no-map condition there was no overall frame of reference to make this information useful, and in the map condition, the map did not have global references on it. Secondly both ego-centred, and local directional information was perceived more useful for making manoeuvres at decision points, and so would always be used in preference to global instructions. It seemed that the use of global directions was for additional information to obtain the overall direction of travel, only being asked for when other critical information needs had been satisfied and the driver had spare cognitive processing capacity.

The use of global references shouldn't be discarded out of hand in terms of their use within a route-guidance system. Global references can be useful for general orientation purposes, especially within a map (Parkes 1989).

Timing of Direction Questions

Direction questions were mainly asked on the approach to a junction. This is not surprising considering the main information being sought was an ego-centred direction in reference to the next junction. The pattern of question asking overtime was similar for both driver age groups. The amount of direction information being sought began to rise at 30 seconds prior to the junction. This was approximately the time at which the junction would become visible to the driver, and so begin to prompt questions. This fits well with the recommendation by Kishi & Sugiura (1993) that the directional information should be given when the turning point can be recognised (e.g. by an intersection sign, traffic signal, or the configuration of the junction). It could become confusing to provide the driver with directional information prior to this point if a turn was required as without identification of the turning point, there would be a much greater chance of turning into the wrong road.

The mean percentage of direction questions peaked at approximately 10 seconds. This appeared to be a critical point for obtaining information, allowing enough time for decisions and lane manoeuvres. The junction at this point would be clear to the driver, allowing them to either ask for a direction (which happened in most cases) or to confirm a direction given earlier. A fairly substantial proportion of the questions were also asked on the final junction approach (i.e the last 5 seconds before the junction was reached). Here many of the questions were confirming previous information given, or the driver had already decided which direction they were going to take (based on their own assumption) and were trying to confirm this. Confirmatory assumption direction questions used on the final approach often caused problems. If the assumption was wrong there was little or no time to change lanes or make the correct manoeuvre and so an error could easily result.

The timings of directional questions highlighted here need to be transformed in order for comparisons with previous research. The studies by Green & George (1995), Green et al (1993), and Ross et al (1997) used measures of distance to establish when direction questions were asked. However the timings used in the present study can be transformed at a basic level, as the speed limits for most of the routes was between 30mph and 40 mph. The effect of speed appeared to have little effect on the time before a junction a question was asked. Therefore using the speed and the most common timing (i.e. 10 seconds) an estimation of distance can be acquired. The comparisons are presented in table 6.1 below.

Table 6.1: Estimates of distances for directional information at 30mph

Study	Distance Prior to Turn
Green and George (1995)	100 metres (based on older female – see chapter 3)
Green et al (1995)	150 metres
Ross et al (1997)	116 - 144 metres (ideal and preferred maximum distances – see chapter 3)
Present Study	134 metres (gross estimate)

The results of the present study were fairly consistent with previous studies. The estimate from the present study would probably be lower as the driver slowing down on the final approach has not been accounted for. However the results are all close when considering that a driver covers a distance of 13m/s when driving at 30mph. So in terms of time the studies by Ross et al (1997) and Green et al (1997) differ by around 1 second on the results obtained in this study (i.e. 10 seconds). It should be noted here that the a studies by Green et al (1995) and Ross et al (1997) were distances based on turning into a side road. The results in the present study, was the aggregate of the all timings in relation to junctions and side roads. In this context it seems reasonable to suggest that the timings of each of these studies is applicable to almost all situations concerning direction information.

Suitability of Direction Information for a Route Guidance System

Direction information was the most prevalent information type sought by drivers *(mean 44%)* forming the fundamental basis for successful completion of the navigation tasks. Such preference for this type of information agrees with previous research (e.g. Burnett 1998;Burns 1997; Daimon et al 1997). Explicit directional instruction should form the basis of any route guidance system. This may seem an obvious statement but it is possible to implement a route guidance system without explicit instruction e.g. a map with a highlighted route, instructions to follow signs. One driver in the field trial only used directional information and managed to successfully complete the tasks.

6.3.2 Distance Questions

Content of Distance Questions

A majority of the distance questions asked by drivers were cost-based, and absolute distances. There was relatively little difference between older and younger drivers for the different types of distance information sought. However there were some gender differences. Female drivers sought a significantly higher percentage of cost-based distance information than male drivers, and this appears to be at the expense of absolute distance information.

The use of cost-based distance questions is consistent with previous research by Burnett (1998). Although Burnett (1998) reported a low use of distance questions, those used were mainly cost-based. It appears that drivers use cost-based distances to acquire some idea of the immediacy of upcoming events (i.e. do they have to do something soon). However Burnett (1998) in a questionnaire survey reported that drivers can find such cost-based distance information 'too vague'. This is the advantage that absolute distances have as they give more specific information. Absolute-distance information in the present study, was used almost as much as cost-based information, and was a majority of the distance information sought by male drivers. Absolute distances not only give some indication of immediacy but also provides more specific information on the distance, for example, before a manoeuvre needs to be made. However as reported by Burnett (1998), many people do not feel confident in judging distances, and this may explain the difference between males and females in the use of cost-based and absolute distances, found in the present study. It is possible that female drivers did not feel as confident at judging distances as male drivers.

Looking at the references of the absolute and cost-based distance questions it can be seen there were a number of combinations. The main references were to either the destination or their current path. Absolute distances in reference to the destination were mainly asked at the beginning of the journey to try and get some idea of the distance that was being driven. Periodically along the journey drivers would then ask how close/far they were from the destination, to keep track of their progress. This was only done when the driver had spare cognitive processing time. If they were close to the destination, this would then prompt further questions to help locate it. Older drivers sought more distance information in reference to the destination (42%) than younger drivers (20%), which suggests this information was important to them.

The distance being sought in reference to the current path allowed the driver some indication as to when they would need to make a deviation. Very few of the questions were seeking distance information for the next junction. This differs from direction questions where drivers sought information junction to junction rather than manoeuvre to manoeuvre. The use of distance questions in this way is more comparable to Daimon (1997), where it was reported that drivers sub-goals were manoeuvre to manoeuvre (though not necessarily in their use of distance information). Knowing that they were to be on their current path for some time or a certain distance afforded drivers situation awareness. For example if they knew that the next time they were to turn off their current path was in two miles, any junctions coming up immediately, would be assumed to be straight on. In this way distance information, indirectly provides directional information on future junctions.

Although drivers sought little relative distance information, it is worth commenting on here as, along with absolute-distance, this information type is extensively used in some current navigation systems. Relative distance is often represented as a countdown bar on a screen which counts down until a driver reaches a certain point (e.g. where they need to turn). However as reported by Green et al (1995), such a count down bar was removed from their final recommended interface, as drivers preferred absolute distances.

Timing of Distance Questions

Drivers mainly asked distance questions on junction departure. This was more so for older drivers than younger drivers. A large proportion of distance questions asked by younger drivers, were on the junction approach. It seems distance questions by younger drivers were not necessarily prompted on departing a junction. For older drivers the departure from a junction often prompted a distance question. This can be seen in the pattern of distance questions over time. Older drivers sought the highest percentage of distance information within the first 5 seconds on leaving a junction. Only a small percentage of distance information was sought at this point by younger drivers, their highest percentage coming at approximately 10 seconds after junction departure where information being sought was almost equal between the two driver age groups. Most of the questions asked at this point were cost-based or absolute distances in reference to a manoeuvre. It seems that there is some level of uncertainty on departure from a junction, which prompted drivers (especially older drivers) to ask for distance questions at this time. This ties in well with previous research by Green et al (1993). They found that drivers looked at the route-guidance system within a few seconds of completing a turn, concluding that they were looking for reassurance to make sure they had made the correct manoeuvre. The results from the present study, suggests this behaviour may also have been to seek information on the immediacy of the next manoeuvre or event.

Distance information on the junction approach, was mainly sought by younger drivers, peaking at 10 seconds prior to the junction. On finding out they were to continue straight on at a junction, this would often prompt younger drivers to then ask how long they were to stay on that road for. Information asked at other times i.e. in-between junctions, for both driver age groups, were mainly distance questions in reference to the destination. Drivers tended to do this in between junctions when they had spare time, as it was not critical to immediate manoeuvres.

No previous research has examined the timing of distance information for route-guidance systems. The only recommendation has been from Green et al (1995), based on drivers visual behaviour on leaving a junction (Green 1993), as described above. Green et al (1995) suggested that immediate information about subsequent manoeuvres would reassure the driver that a previous manoeuvre was correct. Thus a time of 5 seconds after leaving the junction was determined as a suitable timing for distance information on the next manoeuvre. This timing appears to be suitable (especially for older drivers) in light of the current findings.

Suitability of Distance Information for a Route Guidance System

Distance information was the equal third most popular information type sought by drivers *(mean 12%)*, along with sign information. Significant use of distance information in the navigation task has also been found in previous research (e.g. Daimon et al 1997; Akamatsu 1997). This information should be of high priority for incorporation into a route guidance system as it helped reduce uncertainty after leaving a junction especially for older drivers, giving the driver an idea of the immediacy of upcoming events. It is also suggested that such information provided by the map in that condition was partly responsible for the faster route times, thus having a positive effect on the reduction of uncertainty.

6.3.3 Node Information

Content of Node Questions

The most popular use of node information, for both older and younger drivers was as a reference (e.g. *"Which way do I go at the roundabout?"*). Node information can be seen as a very strong navigational cue as it provides the focus of the manoeuvres being made. In most cases it is also unambiguous, as the driver cannot miss the junction i.e. if continue to drive they will reach it. This is an advantage over landmark information being used as a reference, and also junctions form part of the road infrastructure, and are in most cases clearly recognisable.

A large proportion of the direction questions used node information to provide the focus of the direction information being asked for. However drivers reference to the junctions was not always consistent, as many junctions cannot easily be categorised. Roundabouts were always referred to as a 'roundabout' or an island. Crossroads and t-junctions however were often referred to as simply a 'junction'. Any junction types, which did not fit neatly into a category, were simply referred to as 'junctions'. This in context did not cause any confusion as all drivers distinguished between junctions and side roads. Even though a side road is a junction, drivers only classed junctions as that which they did not have automatic right of way. Thus side roads were always referred to as such.

The second most common type of node information being sought was the junction type. Older drivers sought more junction type information than younger drivers though this difference was not significant. Drivers prior to arriving at junctions would ask the type of junction to expect (e.g. roundabout, cross-roads). Firstly looking at the references for junction type questions these were mainly in reference to a manoeuvre or in reference to the next junction. Knowing the junction type at which a manoeuvre needs to be made will aid the driver in recognising that point when they arrive. Also whether the junction type was sought for a manoeuvre or the next junction this will aid situational awareness and expectancy (see chapter 2). Drivers will have schemas of how to act at certain junction types e.g. roundabouts, cross-roads. If drivers are aware of the type of junction approaching (e.g a roundabout), and the direction they need to go (e.g. right), the driver will know in advance that the right hand lane would be required to make such a manoeuvre at a roundabout.

None of the drivers used junction angle information. This does not necessarily make this information useless but was probably more to do with the junctions approached. Most of the junctions and roundabouts as mentioned earlier could easily have left/right tags attached to them. Therefore the angles did not really become an issue. Had larger junctions been approached this may have required such information.

Timing of Node Questions

A significantly higher percentage of node questions, were asked on junction approach than junction departure for both younger and older drivers. This indicates that node information is important to drivers prior to reaching a junction.
The questions on approach to the junction were triggered approximately 20 seconds prior to reaching the junction. This was often due to drivers being able to see a junction in the distance and trying to establish what type of junction it was, or if that was the junction they were to make their next manoeuvre at. The time at which most node information was sought was 10 seconds prior to the junction. Here younger drivers asked a much higher percentage of node questions than older drivers. One of the main reasons behind this was that younger drivers combined node and direction information more than older drivers *(e.g. "Do I go left at the roundabout?")*, and so the timing was the same as the main direction question timings. Older drivers did also combine node and direction information, but were also concerned with identifying the junction *(e.g. Is it a roundabout/crossroads?)* that they could see approaching more so than younger drivers (though this was not significant). This meant the timing of the node information was more spread depending on when they could see the junction, and when they required information on the type of junction approaching.

Although not as high, the percentage of questions asked on the junction approach was still a substantial proportion of questions asked on junction departure. Here questions were mainly establishing what type of junction the driver would encounter next and so providing advance preparation for that particular event. This early information was sought when the drivers had spare time i.e. there were no immediate events to deal with.

There has been no previous research in any form on the timing of node instructions and so no comparisons can be made. For node information which was combined with directional information, the timing established for directional information seems appropriate. For junction type information the only comparison that can be made is with the research by Kishi & Sugiura (1993). They highlighted that the identification of a turning point (e.g. type of junction), should be given when it becomes recognisable. However in the present study drivers wanted to know what an approaching junction was before it became recognisable, otherwise they wouldn't have needed to ask.

Suitability of Node Information for a Route Guidance System

Node information was the second most popular information type sought by drivers *(mean 18%)*. The high use of node information is consistent with previous research (e.g. Alm 1990, Daimon et al 1997; Burnett 1998; Amakatsu et al 1997). This as with directional information is core information required by the driver for navigation and so should be incorporated into any route guidance system.

6.3.4 Landmark Questions

Content of Landmark Questions

Of the landmark information used in the present study the most popular was landmark references (41%), followed by landmark names (26%), landmark locators (24%) and landmark descriptors (9%). There were no significant differences for age.

Landmark references (*e.g. "Which way do I turn __at the traffic lights__?"*) were used in the same way as node references and provided the focus of turn information. Again this helps pin point a place in space and time for where a manoeuvre needed to be made, and was almost used exclusively in combination with directional information.

Landmark name information was mostly used to identify where a manoeuvre needed to be made. Here drivers would often ask the experimenter if there were any obvious signs of their next turn (i.e landmarks). This was often difficult for the experimenter, as there often wasn't a suitable landmark present. Most drivers usually used other means to establish turning points (e.g. node types, distances, simply asking for a direction). These were often more effective due to the lack of obvious landmarks along the route. Landmark name information was also occasionally used in reference to the destination. Here drivers were looking for landmarks that would indicate that they were nearing the destination.

Landmark descriptors were mainly used to obtain descriptive information on the destination building/s e.g. whether the building was modern, how big it was etc. Drivers here were trying to make sure they would recognise the destination when it came into view thus aiding the final stages of navigation in reaching the destination. Landmark locator information was also used in this manner. Although relatively unused by younger drivers, 16% of older drivers' landmark questions were of this type. The purpose was to try and establish which side of the road the destination would be on again to try and make sure they would be able to locate it when it came into view thus easing the final stages of the navigation task.

The different landmarks used by the drivers (except for the destinations) were also identified. These mainly came from landmarks used as references, and landmark names. The main landmark used for manoeuvres was traffic lights, for both older and younger drivers. This is consistent with previous research (e.g. Alm 1990; Burnett 1998; Daimon et al 1997). Traffic lights are very much part of the road infrastructure, are well known, easily recognisable, and feature on many junctions. Because of this it was used in very much the same way as node information for pinpointing manoeuvres and recognising junctions. However a third of the questions referring to traffic lights were erroneous. This was because drivers mistook pedestrian crossings for junctions. This could be seen to cause problems if an instruction is given to a driver to 'turn left at the traffic lights' as these crossings were often near junctions containing traffic lights, and side roads were often near a pedestrian crossings to further confuse matters. Other landmark types were used relatively little. The footbridge and petrol garage were again used for manoeuvres. Interestingly in using the garage to identify the left turn one of the participants actually mistook the entrance of the garage for the turning, and drove onto the forecourt. The fast-food restaurant was used to try and locate the cinema (one of the destinations) with the reasoning, that these are often located close together.

Timing of Landmark Questions

There was no difference in the percentage of landmark questions asked on junction approach or junction departure. This was due to the fact that the references of the landmarks varied between the destination and manoeuvres, and so information was required at different times. This applied to both younger and older drivers.

The pattern of timing between the two age groups was very similar. On approach to the junction the main questions were asked at approximately 10 second prior to reaching the junction. The main reason for this peak was due to the high use of landmark references. As explained earlier landmark references were in combination with directional information and so the timings were very similar (direction timings were approximately 10 seconds prior to reaching a junction). On junction departure questions were either related to finding out information on the destination (description/location) while the driver had spare time, or seeking landmark information for the next manoeuvre.

No previous research has examined the timing of when landmark instructions should be given to the driver. However comparisons can be made with the suggestions from Kishi & Sugiura (1993) and Green et al(1995). Kishi and Sigiura (1993) suggest that landmark information should be given when the relevant landmark becomes recognisable. This would generally agree with 10 seconds prior to reaching the junction (an approximate distance of 134 metres at 30mph), as this is where landmark references were often used (and therefore the landmarks must have been visible). Green et al (1995) highlights two timings at which landmarks could be given. Preparation information containing landmarks could be given 1500 metres prior to reaching the junction and as approach information 150 metres before the junction. The distance of 134 metres (10 seconds prior to the junction) found in the present study for junction approach is not too far different from the second of these, and therefore appears reasonable. However drivers in the present study did also seek early landmark information at times after leaving the junction in order to be able to identify a manoeuvre. It is difficult to establish how far before a junction this was as such information was related to junction departure rather than junction approach, and so should be given at a set time distance after leaving a junction. Therefore the 1500m prior to a turn highlighted by Green et al (1995) is probably not a suitable guideline.

Suitability of Landmark Information for a Route Guidance System

Landmark information was one of the least popular information types sought by drivers *(mean 9%)*. This is in contrast to much previous research where landmarks have been identified as key information for navigation (e.g. Burnett 1998; Burns 1997; Daimon et al 1997; Alm 1990). The reasons behind this are due to the methodologies employed. In the case where a person has been sketching a route for another person or themselves to follow (e.g. Burnett 1998; Daimon et al 1997; Alm 1990), then landmark information is needed for two reasons. Firstly it acts to confirm the person is on the right track e.g. "after turning drive on, and you should pass the kings head pub on you left". As the person will have no other navigational aids these are important to help avoid uncertainty, and continually give the person confidence they have made the correct turns. Secondly landmarks are used in these situations to identify a manoeuvre e.g. turn right at the crossroads with traffic lights and a church on your left. In this situation the landmark acts to pinpoint where the manoeuvre is in space and time. However with the methodology used for this experiment, the driver no longer needed to rely on landmarks for confirmation or to pinpoint a manoeuvre in space and time. The methodology was applied so the experimenter would act as and 'ideal' route guidance system (knows everything about the route and so can provide information on request at the times needed). Therefore the driver would no longer need to know if they had made a correct turn and were travelling along the right road as they would know depending on the information given for the previous manoeuvre or they could just ask. Also in order to identify if they needed to make a turn at a particular roundabout they could just ask (e.g. "Is this the roundabout I need to turn left at?"). Another external source no longer needs to pinpoint the turn or the correct junction to make the turn at.

The task of sketching routes to follow is essentially a route planning task, and is very different to real time navigation. The present study seems to indicate that the real-time navigation scenario there is little need for landmarks. In current literature landmark information has been seen as a key for the provision of good route guidance information. Indeed there have been studies, incorporating landmarks into a route guidance system, looking at their potential use, and effectiveness (e.g. Alm et al 1992; Green et al 1993; Bengler et al 1994). Such studies where landmarks have been incorporated into route guidance information, have shown positive benefits. However these have not been compared to incorporating other combinations of information. It is agreed that landmarks could help the driver, but even if this is the case it is almost impossible to incorporate them. When considering all of the factors which will make a good landmark (e.g. visible, recognisable, permanent, visible at night), it becomes clear that there are very few landmarks which will fit these criteria. So to use landmark information, the landmark firstly needs to be present, and secondly, needs to fit the criteria. Even so landmarks that do fit the criteria (e.g. traffic lights), in the present study were shown to be associated with errors.

In the present study there were only a few suitable landmarks located at turning points which could have aided the driver. If this occurs in very few situations then an alternative method would be required on a majority of the manoeuvres which need to be made. In terms of consistency, this would be the better option to maintain for all route guidance instructions.

6.3.5 Path Questions

Content of Path Questions

The most popular path information used was prior path information, followed by path class information, lane information, and path geometry. There were no significant differences between older and younger drivers.

Prior path information was used when the driver had already established that they were required to turn into a side road. The information was used to establish which road it was *(e.g. "Is it this road or the next one I turn into?").* This information was only needed towards the end of the journey, where side road turnings were required.

Often when they knew they were close to the destination they would begin taking more notice of the side roads. This included slowing down as they were approached, while trying to establish if they needed to make a turn *(e.g. "Will I need to make a left turn into one of these roads?").* This is often a situation where landmarks are deemed to be a suitable for identifying a manoeuvre. However many side roads did not contain a suitable landmarks which could be referenced and so renders such an information type useless Burnett (1998) highlighted that drivers had to adopt other methods due to the lack of availability of landmarks. Other methods of indicating the road include the road name and distance, or giving a count (e.g. the 2nd road on the left).

Path class information was used by drivers to either establish whether the road they were travelling would remain the same *(e.g. "does this become a dual carriageway?"),* or the class of the next path they were going to turn *onto (e.g. "do I turn onto a main road next?").* It is unclear why drivers would establish whether the current road would remain the same. It may have been to improve general situation awareness of future events (e.g. the changing from a rural road to a main road indicates the driver is getting closer to the city, therefore more traffic, more junctions, different speed limits etc). The reasons for establishing the path class of the next road seemed to be to aid in identifying when a deviation from the current path was required. Also again it could have also been to gain situation awareness of the approaching road environment.

Lane information was the second most popular path information for older drivers, whereas younger drivers hardly used lane information at all. Although this difference was not significant it does suggest that older drivers would prefer lane information. Burns (1997) and Burnett (1998) found that drivers generally perceived such information as useful, especially in inner-city situations. Burns (1997) also found that older drivers had a preference for such information. This would take some of the decision making away from the driver allowing early manoeuvres into the correct lane position to take place. In the present study drivers were often able to obtain enough information regarding directions, to be able to assume which lane to take (e.g. knowing you are turning right at a roundabout, would normally mean an approach in the right hand lane). It seems however that older drivers may not have made such assumptions or simply preferred confirmation of what they were about to do, as lane choice often limits the turns which can be made.

Path geometry was not widely used by drivers. They did not appear to be interested in such information and so was not central to information being sought. It seemed that drivers were not interested in the geometry of the road but in simply identifying their next manoeuvre point or junction. This is very much working at the first level of navigation knowledge i.e. procedural knowledge (Wickens 1984; Kuipers 1982), as described in chapter 2. Therefore the details of the geometry of the connection between these points was not of interest to the driver.

Timing of Path Questions

There was no difference in the percentage of questions asked on junction approach as compared to junction departure. This was the same for both older and younger drivers. Depending on the type of path information being sought, questions were triggered by the approach of a junction or the departure from a junction, which can be seen by the pattern of questioning over time. This pattern was also similar for younger and older drivers

On the junction approach a majority of the path questions started to rise at approximately 20 seconds prior to reaching the junction peaking at 10 seconds. Path questions here were establishing which lane to take (this would have to be done prior to the final approach i.e. the last 5 seconds, to have time to get into the correct lane), and establishing which side road was required. Older drivers had a higher percentage of questions at the 10 second mark due to a higher percentage of lane information being sought.

On junction departure a majority of questions were asked approximately 10 seconds after departure. Questions here were again establishing prior path information as the driver realised they were nearing the destination, and so would soon need to turn off.

Questions asking about path classes appeared to be in between junctions, when the driver had spare time to deal with such information, as it was not seen as critical.

Direct comparison of timings of some of the path information can be made with the research by Green & George (1995) and Ross (1997). In both cases the timings were calculated for a turn into a side road which is the same as prior path information. As established here the need for information on the turning into a side road was at approximately 10 seconds prior to reaching it. This therefore provides the same comparisons with the timings established for direction questions, which is favourable (see table 6.1). There have also been recommendations for lane information. Kishi & Sugiura (1993) recommended that drivers should receive lane information 700 metres prior to a turn (though this was not on UK roads). Drivers in the present study sought most lane information at approximately 134 metres (10 seconds prior to the junction at 30 mph). This is a vast difference it suggests that 700 metres is possibly too early to give such information (especially on UK roads).

Suitability of Path Information for a Route Guidance System

Path information was the least popular information type sought by drivers *(mean 7%)*. Comparisons with some previous research is difficult as there are different definitions as what path information is (e.g. Daimon et al 1997, classed distances as path information). Also methodologies involving route sketching will contain much path information, as paths connecting various nodes and places drawn. However some comparisons can be made with previous research adopting similar categorisations as the present study. Path information has been highlighted as useful in a number of studies especially in urban environments (e.g. Burnett 1998; Burns 1997). Path information has not generally been seen as critical in terms of the provision of route guidance information as compared to other types of information (e.g. directions, landmarks and signs). The low use of path information here does not mean it is not useful, but is dependent on the situations encountered as to whether it is required (e.g. much prior path information will be required if there are many turns into side roads).

6.3.6 Sign Questions

Content of Sign Questions

The most popular sign information was place names followed by point of interest, road numbers and street names. There were no differences between older and younger drivers. However there was a gender difference. Female drivers sought a significantly higher percentage of point of interest names than male drivers.

Place names appeared to be important sign information for the drivers. Drivers used place name information for two main purposes. Firstly to establish the location of the destination and secondly to establish where they were. Drivers in trying to establish the location of the destination would firstly try to identify the general area in which it was situated. This would allow them to follow signs in order to get to the general area. Drivers would then narrow the search and ask for a district information, again allowing signs to act as navigational cues. Drivers as they progressed would like to know the area in which they were currently driving (especially older drivers). This appeared to be to allow them to gauge their progress along the route in terms of knowing if they were in the same area as the destination. Point of interest names were used further here mainly by female drivers in order to narrow the search even further. This included for example the actual name of the complex the cinema was located, or if it was on an industrial estate. This again allowed the driver to make use of any road signs which would narrow the search even further. It is unclear why female drivers required more specific sign information in relation to the destination location, though Schraagan (1990) has identified that female drivers use less spatial information and more sign information than male drivers (though this was in relation to street names).

Place name information was also occasionally used to make a manoeuvre at a junction, rather than in reference to the destination or driver *position (e.g. "Do I turn towards Nottingham?").* Here the driver had identified information on a road sign in relation to the turn they wanted to take. The low use of such information suggested that other information types were more suitable for making actual manoeuvres. However, as described earlier, the junctions encountered had a maximum of four exits. Had the junctions been more complex, identifying which exit to take through the use of sign information may have proved more desirable.

Road numbers and street names are very similar information types i.e. they attach a label to a path. In both instances this information was mainly used when a map was present and partly accounted for the increase in sign information in the map condition. Without a map this type of information was used less as drivers sought other information in order to navigate the routes successfully. Burnett (1998) also found that drivers would note more street names and road numbers when using a map to plan a route, as compared to seeing a video of the route. The use of road numbers and street names allowed for information to be taken from signs and so drivers could locate the next path they were to turn onto. However actual road names were not often present or were on a sign far removed from the main traffic signs. Drivers when using the map would often try to memorise each of the road names they were going to turn into. This became obvious as memory failures began to happen and the drivers would ask for name of the next road as they couldn't remember. This method of navigation was very poor as drivers would spend a lot of time searching for such information. This is consistent with Schraagan (1990) who found that poor navigators had a high reliance on street signs. Such behaviour in the present study contributed to the correlation with longer route times in the map condition.

Timing of Sign Questions

More questions were asked on junction approach than junction departure though the difference was not significant. There were no significant differences between older an younger drivers. Sign information therefore is important on the approach to a junction more so than junction departure.

The pattern of questioning over time on the junction approach revealed a sudden increase in questioning 10 seconds prior to the junction. This continued to rise until the junction was reached. Questions here were related to street names, road number and place names. If the driver was stopped at a junction they would often ask the name of the next road (especially if the information had previously been obtained from the map). Also they would confirm the place name for the signs they were following *(e.g. "Am I still following the signs to Derby?").*

On junction departure questions were asked over the 50 seconds after leaving. Here questions were related to the area in which the destination was located, and was mainly information sought when the driver had spare time. This could then be used for sign following giving the driver more navigation cues.

There has been no previous research on the timings at which sign information should be provided to the driver. The suggestion by Kishi and Sugiura (1993) is to provide information when the sign becomes recognisable. This appears to be consistent with the timing found in the present study as sign information was acquired on the approach to a junction, when the driver could read the sign information. However this was often to confirm information they had acquired earlier, on the name of the place/area to which they were travelling. If sign information is to aid in making a manoeuvre then information on a common timing with direction questions appears appropriate (i.e. 10 seconds prior to the junction). Other information such as place names for their destination or current position should be provided when the driver has spare time.

Suitability of Sign Information for a Route Guidance System

Sign information was the equal third most popular information type sought by drivers *(mean 12%)*. This finding is consistent with previous research which has also highlighted significant use of sign information (e.g. Burnett 1998; Burns 1997; Amakatsu 1997; Schraagan 1990). In the present study they were not seen as core information, especially when there was no-map present as the use of such information significantly reduced. However they should be incorporated in some form into a route guidance system. They can be particularly useful at complex junctions for aiding the driver, and provide extra navigational cues. Also they form part of our current road infrastructure and are one information type drivers are used to using.

6.4 Driver Navigation Strategies

The information from the analyses of the content and timing of the questions asked by drivers gave an abundance of different types of information. On the face of it the way in which drivers navigated was very complex, as they switched between seeking different types of information relative to junctions, manoeuvres, current progress along the route, and the destination. The previous section dealt with each of the information categories separately. This section attempts to put these together looking at the motives of the driver for the different types of navigational information sought, and the different stages at which it was required. The reasons for this were to provide a template for the design of route guidance systems' information content and timing.

*6.4.1 Driver Navigation Model**

The navigational information sought by drivers can be seen as consisting of three different conceptual levels, depending on the motive, mental workload, and uncertainty of the driver.

- **Macro Level** – *Overall goal* (e.g. information related to the destination)
- **Meso Level** – *Intermediate goals* (e.g. information related to the manoeuvres required to achieve overall goal).
- **Micro level** – *Immediate goals* – (e.g information allowing an approaching junction to be negotiated).

Information sought by drivers at the micro level induced little mental workload, allowing the drivers to quickly process the information in times of high uncertainty, where the information was critical to the task. Information sought at the meso and macro level was more detailed in its nature, and provided the driver with a preview of the route ahead in terms of identifying the next manoeuvres, progress along the route, and location of the destination. Drivers sought such information when workload was low and so they had spare capacity to deal with the information. Figure 6.1 details the different stages at each of the different levels highlighted.

*This research was presented at the International Conference on Transport and Traffic Psychology (Janes & Galer Flyte 2000)

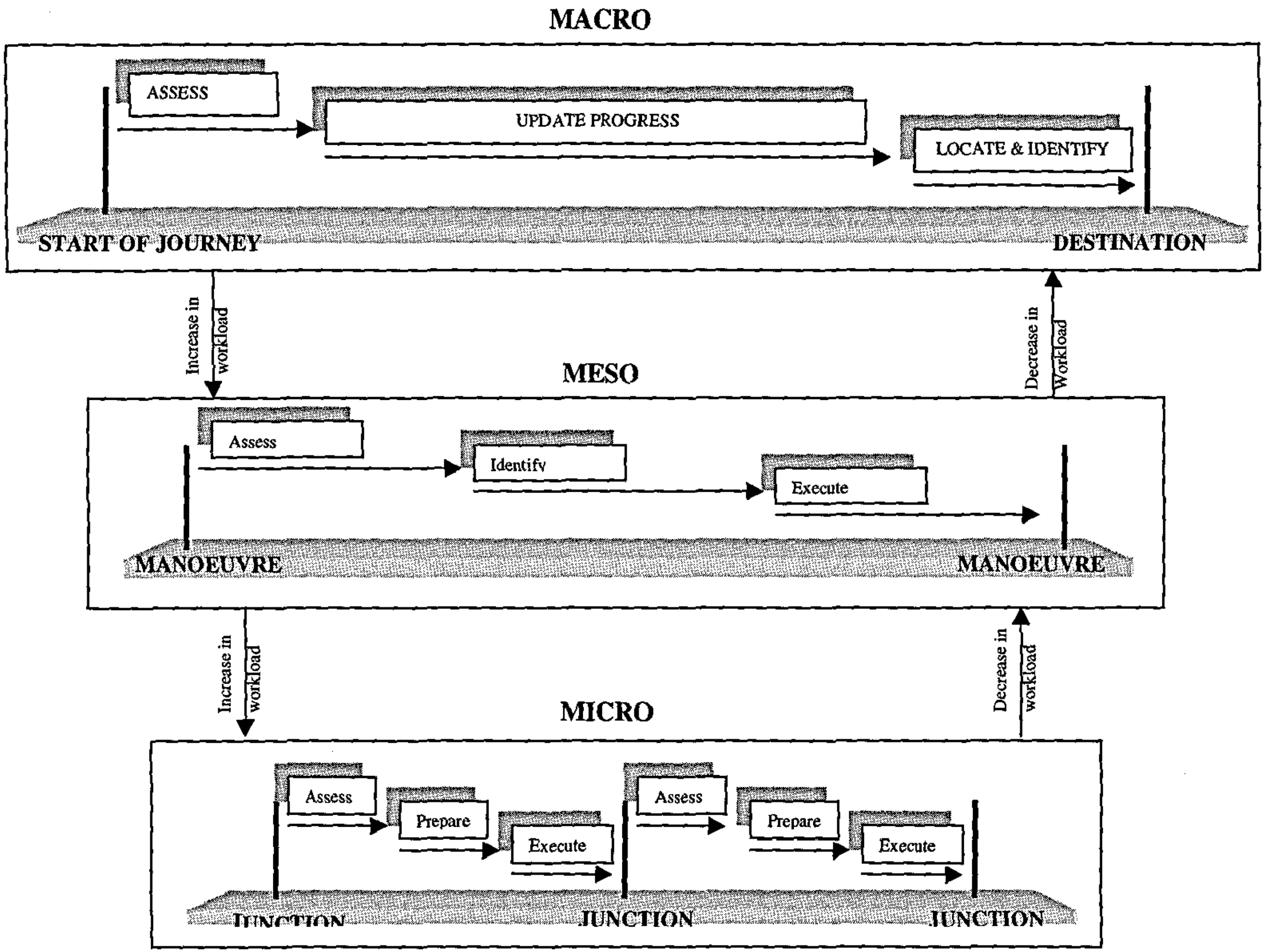


Figure 6.1: Stages of the navigation process on each of the three different levels

Macro Level

Information being sought here was specifically aimed at gaining information on the route as a whole. There were three stages involved here, each of which is explained below.

- *Assessment* - At the beginning of the journey the driver would require general information on the route they were about to travel, including distance to the destination, the types of road being travelled (e.g. main roads, dual carriageways), and general area the destination was located (e.g. city centre, city outskirts). This gave the driver a general overview of the route being travelled.

- *Progress* – Periodically along the route the driver would update their current status in reference to reaching the destination. This included information such as where they were (i.e. the name of the area they were travelling through), and how far from the destination they currently were. This allowed drivers to chart their progress, allowing them to know if needed to ask further questions at this point in time (e.g. in order to pinpoint the destination).

- *Locate and Identify* – Once the drivers realised they were getting close to the destination they would begin to ask more specific questions in order to locate it. These ranged from special place names (e.g. the name of a leisure park or industrial estate), to descriptions of the destination. This allowed the driver to use any relevant road sign information or to be able to identify the destination from a distance, thus also aiding their navigation.

This level of information was only sought when mental workload was low. By asking for information such as place names throughout the journey drivers would have extra navigational cues from signs. Also it seemed important for drivers to know the status of their progress. Burnett (1998), also highlighted that drivers over a route use such information for orientation and confidence purposes.

Meso

Information being sought at this level involved the manoeuvres required to reach the destination. This level consisted of three stages at which questions were asked, each of which is explained below.

- *Assessment* – At this stage the driver was establishing the next time they would need to turn off the road, by asking for distance *information (e.g. "Do I stay on this road for 1 or 2 miles")*. Even though drivers are poor at judging distance the reason behind this information was not for exact judgement purposes. For example if the driver knew they were to stay on a road for two miles, they would know to go straight on at any junctions that come up within a short time of instructions being given. Thus it will afford some situational awareness indirectly providing directional information for junctions. Also knowing that they were to stay on the road for a period of time also meant that workload was lowered. This afforded drivers time to ask further information on the macro level, or continue seeking information on the next manoeuvre.

- *Identification* – Information being sought at this stage of level two was to identify where or what to turn at. This usually led the driver to seek information on a node *type (e.g. "Is it a roundabout I need to turn at")*, or landmark information in order to identify where to turn. The direction of the turn, which needed to be made, was also sometimes sought at this stage. Seeking both types of information at this stage again lowered workload and allowed further information to be sought at the macro level.

- *Execution* – Once the driver had established where they needed to make the turn, directional information would be sought, or confirmed, to allow execution of the manoeuvre.

This level of navigation was used when drivers could see, or knew from previous information that there were no imminent events, and so workload was reasonably low. For example if the driver after making a manoeuvre was presented with a long straight road ahead of them with no immediate side roads or junctions, then this allowed the driver to plan their next manoeuvre in good time and reduce future uncertainty.

This level of the navigation process is closest to other models of the information needs of drivers in real-time driving reported in previous literature (i.e. Burnett 1998; Daimon et al 1997). Daimon et al (1997) reported that junctions in between manoeuvres were of relatively little interest to the driver. However the present study found this not to be the case, and drivers still sought information on the junctions in between such as the type of junction and confirming they were going straight on.

Micro

The information sought at this level was the most basic and allowed the driver to perform the navigation tasks in times of high workload and uncertainty. There were again three stages of this level, each of which is explained below.

- *Assessment* - On leaving a junction the driver would be faced with a new unfamiliar road ahead of them. If there were side roads or junctions ahead of them this led to a situation of high uncertainty. The first task was to ascertain if they needed to do anything immediately, in order to have time to prepare. This was normally in the form of a cost based distance question (e.g. "Keep straight on for a bit?") or a relative distance (e.g."Keep going up to the next junction?"). If the driver established they did not need to do anything straight away this lowered the workload, and allowed assessment at the meso level. If there were immediate events occurring the driver would then focus on preparing for these.

- *Preparation* – This stage involved drivers establishing the type of junction they were going to encounter (e.g. roundabout, crossroads, t-junction). Sometimes at this point in time directional information would also be acquired. The driver would already have expectations of what a roundabout looks like and how to negotiate such a junction, through schemas developed over time, and so knowing in advance would aid situational awareness and decision making.

- *Execution* – On the final approach to a junction the driver now needed to seek information in order to be able to negotiate the junction. The main information required at this point was directional information and lane information. This then allowed the driver to execute the required manoeuvre. After the junction had been negotiated the process began again.

This level of navigation was the most appropriate for high workload situations (e.g. many junctions, multiple lanes, high traffic volume) as the driver would not have much time to prepare and so would seek basic information which could be acted upon quickly.

6.4.2 Age Considerations

From the discussion in section 6.3, it was clear that there were some age differences in the way drivers navigate. Relating these to the model it is worth noting that the assessment stages of all three levels are particularly important for older drivers. This is suggested as older drivers had a preference for distance information relevant to the destination, and the departure from a junction quickly prompted distance questions relating to their current path. Also at the execution stage of the meso and micro level lane information is also an important factor to consider for older drivers, due to their preference of such information.

6.5 Recommendations

The model described in the previous section should certainly not be seen as rigid. Not all drivers required information at every level, or at every stage within every level. A majority of the drivers sought information at the micro level. Because it provided simple basic navigational information it formed the basis for the drivers' strategies in nearly all situations. For example it was possible to simply ask for a direction every time a junction was approached in order to reach the destination. Indeed one driver completed the task using this single piece of information every time a junction was encountered.

Drivers would however supplement information at the micro level with that from other levels. For example absolute distances to the next manoeuvre (meso level), were often sought when the driver realised they did not have to do anything immediately. Even if further information on the manoeuvre was sought (e.g. what to turn at), drivers still wanted information on the junctions encountered prior to this manoeuvre (e.g. junction type, confirmation that they were to go straight on). At periods when information requirements at the micro and meso levels were satisfied and workload was low drivers would then focus their attention on information at the macro level.

The recommendations presented in table 6.2 form the basic content and timing requirements that a route guidance system should satisfy. These are mainly based on information at the micro level (i.e. information being provided junction to junction), as this was the most used strategy by drivers. These recommendations have been made taking into account the needs of the older driver (particularly the assessment information). However they should also satisfy the requirements of younger drivers as differences between the two age groups in terms of the content and timing of information were not that great.

Table 6.2: Content and timing recommendations for a route guidance system

Stage	Timing	Information Content	When to use	Example Instruction
Assessment (Information only provided if junctions are more than 25 seconds apart)	0-5 seconds after leaving junction.	Absolute distance in reference to current path	Driver has turned onto a new path. The next manoeuvre is greater than 60 seconds away	Follow road for 2 miles
		Cost-based distance in reference to current path	Always except when above rules apply.	Keep going straight on
Prepare (Information only provided if junctions are more than 20 seconds apart	20 seconds prior to junction.	Node type in reference to next junction	The driver is approaching a junction.	Roundabout/Junction approaching
		Prior path information in reference to	The driver is approaching a side road.	Left turn approaching
Execute (Information only provided if junctions are greater than 5 seconds apart)	10 seconds prior to junction	Ego-centred direction combined with node reference for the next junction	When approaching junctions with 3 exits (angled so left/straight on/and right tags naturally apply.)	At the roundabout/junction turn left
		Ego-centred direction combined with an absolute distance	When approaching a side road.	In 100 yds turn left

On leaving a junction the driver is provided with distance information. The present study indicated that information at this time was particularly useful for older drivers. Distance information gives the driver the some idea of the immediacy of the next event, and the instruction itself will act as a confirmation that the correct manoeuvre has been made. Time rules apply here. If on turning onto a new path the driver is to maintain that course for some period of time (e.g. 1 or 2 miles) then an absolute distance should be given (see figure 6.2) (otherwise a cost based distance should be used). This will help in lowering workload, and aid situational awareness, as the driver will be able to assume straight on directions for junctions occurring within this distance. Cost based distances should be given after leaving each of these subsequent junctions (see figure 6.2). Drivers are poor judges of exact distance and so this information acts as confirmation to maintain their current course. If the time between two junctions falls below 25 seconds, then assessment information should not be given due to insufficient time. At this point the preparation information should be given instead to provided the driver with enough time and information to negotiate the upcoming junction.

The preparation information is in the form of a junction type or prior path depending on the situation. In a description of a nodes, roundabouts should be referred to as 'roundabouts', t-junctions as 'the end of the road', and any other junction type (e.g. crossroads) referred to as a junction. This is based on how drivers described various node types. For prior path information, side roads should be referred to as 'left/right turns'. If visual information is provided of the junction type or prior path then the direction information should be given also, as it does not make much sense to simply present the junction layout alone. Time restrictions are applied because if the time between junctions is less than 20 seconds there won't be time to provide preparation as the driver will need execution information fairly quickly.

The information to allow the driver to negotiate a junction depends on the type of junction encountered. A combination of a direction and a node reference for relatively simple junctions. This confirms to the driver the point at which to turn already given in the preparation information, and then provides the direction in which to turn. If the junction is complex (i.e. many exits) then it is suggested that a local direction is used with additional sign information to aid in the identification of the correct exit. This however needs further research as the present study did not contain many junctions of this type. Also there is evidence based on the present study and previous research (e.g. Burns 1997), that older drivers would require lane information on the approach to junctions. However how to incorporate such information into the recommendations already made is not clear. This information may prove useful, especially for older drivers, though further research is required before recommendations can be made.

For the execution of a side road manoeuvre an ego-centred direction combined with distance information is recommended. It is possible that further information could aid the driver in making turns into a side roads, such as landmarks. However as discussed previously other sources of information would be required in their absence. Another possibility is street signs which may help the driver confirm the correct turn. Again though there are problems as the driver would need to locate the street sign providing it was present and visible. Further research on these issues are required.

Time rules for execution information again apply here. If the travel time between two junctions falls below 5 seconds the there will not be time to provide the execution information. In this situation a double instruction would be required prior to reaching the first junction *(e.g. "At the roundabout turn left and then take the next right").* This provides a unique situation to deal with, one which requires further research.

Figure 6.2 provides an example of a scenario employing the above recommendations to help clarify their use. The process is continually repeated following the rules applied to each type of information given at each stage.

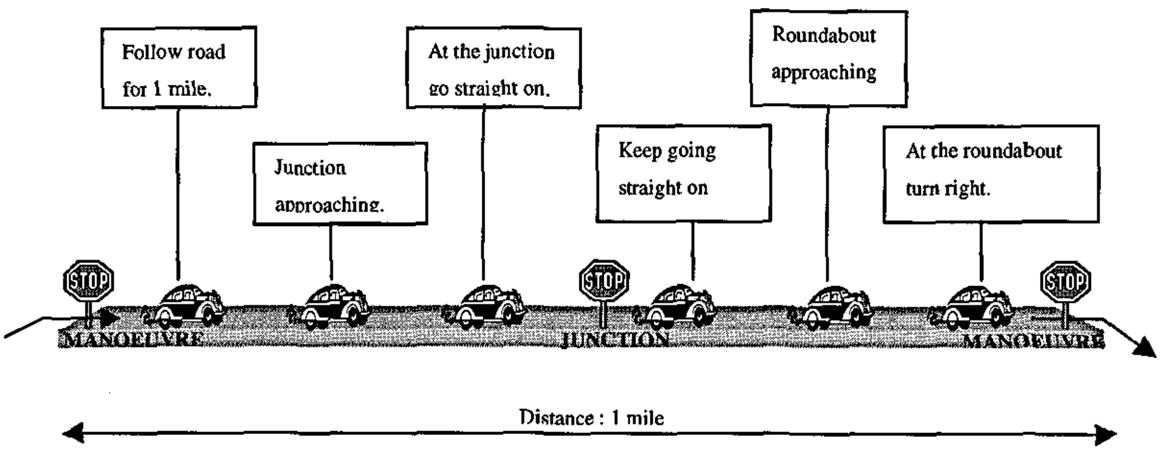


Figure 6.2: Example of the route-guidance instructions based on the recommendations

The recommendations here provide the basic requirements for a route guidance system. This information alone being provided to the driver should aid the driver in the navigation task, reducing uncertainty and workload with minimal distraction. Further information recommended to supplement this information would be sign information. Information on place names of the drivers current position and the location of the destination would provide extra navigational cues for the driver. This information should be constantly available to the driver to be acquired in times of low workload. Also older drivers had a preference for information on the distance to the destination. This information again should be constantly available to the driver to be acquired in times of low workload.

6.6 Conclusions

This chapter discussed the results of the field trial. Drivers mainly required information on direction, nodes, sign and distance information. The lack of landmark information required by drivers highlighted the differences in information required for route planning and real time navigation. The two conditions (map vs no-map) highlighted how information needs change depending on whether a preview of the route has been seen. Having a map prior to driving increased the use of sign information and decreased the use of distance information. Having the map also produced quicker route times, though this is believed to be due to distance and node information being acquired from the map rather than the sign information. These findings highlight that care is needed when suggesting the content and timing of route guidance systems based on trip planning information, or traditional methods of navigation (i.e. a map), as there are differences.

The detailed breakdown of the information in terms of their content and timing led to a driver model and recommendations. These were detailed enough to be of use to designers as they contained rules of use and specific information on timings. The model detailed that drivers required different information at different stages of the navigation task and on different levels depending on their workload, uncertainty, and motives. The three levels depending on whether the information required was in reference to the destination (e.g. distance, location), a manoeuvre (distance, what to turn at), or a junction (next junction type approaching, direction). Drivers were found to mainly use information at the lowest level working from junction to junction. The recommendations based on this suggested that the core of a route guidance system should consist of assessment information (distances) being given shortly after leaving a junction, preparation information (node type) on the approach to a junction, and execution information (e.g. directions) to allow the junction to be negotiated. Other higher level information should be available to the driver when they have spare processing capacity (i.e. in times of low mental workload).

6.6.1 Age Considerations

The field trial overall showed many similarities between younger and older drivers. However there were a few important differences. Older drivers tended to make more errors than younger drivers due to making more assumptions in the navigation task (e.g. assuming they were to go straight on at a junction either confirming this very late, or making an incorrect turn). This is important as it highlights the need for concise clear instructions, at the correct time to stop this from happening (i.e. instructions provided in good time will prevent the driver from making their own decision based on limited information).

Looking at the content and timing of information, it was important for older drivers to receive distance information shortly after leaving a junction. This factor was reflected in the recommendations suggested. Just after leaving a junction there is uncertainty. Information is required to indicate the immediacy of upcoming events, and when presented by a route guidance system can indirectly confirm that a correct manoeuvre has been made. Older drivers at the start of the route also had a tendency to seek information on the distance to the destination more so than younger drivers.
The third main difference was a trend for older drivers to ask a higher percentage path information than younger drivers. This was mainly due to seeking more lane information prior to junctions. This has not been incorporated into the current recommendations as overall the use of path information was low for both driver groups (and therefore other information was seen as more important). Also it was not clear how to incorporate this information with that already present without making the route-guidance instructions too complex.

One final observation concerning age was the variability within the results. It became clear as analysis took place that the variability of the results from older drivers was consistently higher than that of younger drivers. Designing for this population is therefore much more difficult as individual needs within this group can differ to a much larger degree. This adds some sensibility to the grouping of older drivers into further categories as mentioned in chapter 2.

Chapter 7: Information Presentation and Modality

7.1 Chapter Summary

This chapter introduces literature on the presentation of route guidance information, covering modality (verbal/ visual) and the information presented within each of these domains. The literature is reviewed and discussed highlighting the best modality and presentation for route guidance information, and where knowledge is required concerning these issues and older drivers.

7.2 Introduction

Chapter 6 defined the content of the information useful for route guidance and the timing of this information. The best ways to present this information now needs to be defined. There are two questions, which need answering:

- What is the best modality for information presentation (e.g. auditory, visual)?
- What is the best design for the presentation modality (e.g. maps, arrows, text, speech)?

These two areas are very much inter-linked, as some design issues will dictate presentation modality e.g. maps cannot be presented verbally. However many of the types of information required by drivers can be represented in both modalities e.g. some text instructions can also be spoken.

The human factors issues involved in this area are vast. Considerations need to be made for the capabilities of the driver and the driving task being performed. Chapter 2 highlighted the limitations of older drivers with respect to the driving task. As we age there are declines in our sensory, cognitive and attentional resources. A system, which is easily used by a younger driver, may not be suitable for an older driver. However a poorly designed system ignoring human factors would be poor for all drivers. It is important that the attention required by the route guidance system for successful navigation does not interfere with the primary task of safe driving (highlighted in chapter 2) thus making the navigation task more demanding than it already is (Schraagan 1993). The aim is to provide route guidance information which affords good perception, quick processing and fast decision making. This in turn will facilitate safe driving and successful navigation.

One of the problems with providing route guidance information is that the driving task itself can be highly demanding on the driver's attentional resources. Even without such a secondary task, inattention contributes to between 30 and 50 per cent of accidents (Treat et al 1979; Sussman et al 1985). The driver can therefore easily reach cognitive overload with competing stimuli from within the vehicle due to the brain being a limited channel for processing information (Wickens 1980). However the brain does have various channels for input and it is possible to perform a number of tasks at once through time-sharing. The efficiency of this time-sharing for the input modalities (visual vs auditory) will be better when attention is divided between one visual and one auditory channel rather than two visual or two auditory channels (Wickens et al 1997). As driving is mainly a visual task with most information being gathered through the visual channel (Rockwell 1972) it would seem therefore unwise to add a competing visual task. Therefore, the auditory channel would appear to be the most suitable for route guidance. However, there will be some spare capacity for information to be obtained through the visual channel, and visual information does have some distinct advantages over auditory guidance, for example presenting the road layout at a junction is best suited to visual presentation. The efficiency of the time-sharing will also be effected by the complexity of the route guidance instructions presented to the driver i.e. the more complex the message the greater the processing capacity required for either input modality.

There have been a number of studies which have looked at the presentation of information for a route-guidance system, looking at modality and the different designs within each presentation modality. In one of the early experiments Streeter, Vitello and Wonsiewicz (1985) compared customised maps with vocal directions recorded on a tape, the tape and map combined, and a normal paper map (used as the control condition). The voice instructions were recorded using a female voice and were designed to:

- Give information on distance between turns, street to turn onto, and direction of turn
- Inform the driver of an approaching turn
- Indicate error conditions, i.e. when the driver has gone too far
- Repeat the most essential instruction to aid memory.

The customised maps were colour schematic maps showing the route to be travelled in red. The maps contained the same information as the voice instructions i.e. mileages, landmarks, streets before the next turn, direction of turn and major streets beyond the turn. The control group were given a map and an address and were instructed to find their way to the destination using whatever means they would normally use. Fifty-seven participants took part in the experiment, predominately females of unspecified ages. The participants drove on three different routes using one of the four methods of route guidance. The dependent measures recorded were time to complete the route, distance travelled, number of turns, number of repeats of the taped instructions, number of referrals to the map, number of errors for each instruction, and a description of each error. Participants' performance was found to be the best for the taped voice instructions, producing shorter distances travelled, shorter journey times and fewer errors. Most navigational errors were committed in the normal map condition. Subjective ratings of each of the conditions also favoured the voice instructions only condition though one of the negative aspects highlighted for this condition was the lack of an overall plan of the route. Streeter et al. (1985) highlighted however that the use of auditory instructions was not solely responsible for the improved performance, but for a large measure was due to the nature of the instructions (guided from research on navigation and basic psychological findings). They concluded from this research that a route guidance system should be voice orientated given their superiority over maps.

Van Winsum (1987) also showed a superiority of verbal guidance instructions over conventional maps. In the verbal condition, simple 'left-right' instructions were given to the driver by the experimenter. This was compared to a displayed map. In the map condition participants on average made 2.2 navigation errors, where as no errors were made in the verbal instructions. The relatively high number of errors in the map condition was due to participants miscounting side roads when trying to update their position on the map.

In the above studies attention has only been focussed on the comparison of verbal instructions and maps. However map displays are not the only visual displays possible. Verway and Jansssen (1988) conducted a study in which participants had to drive a specific route comparing a memorised map with system generated verbal instructions and system generated visual instructions. The verbal guidance consisted of simple 'left-right' instructions and the visual instructions consisted of arrows pointing 90 degrees to the left or right. Participants were asked to drive a specific route, with wayfinding performance as the dependant measure. The study showed significant advantages for auditory route guidance on navigation errors (average number of errors 0.42) as compared to the visual instructions (average number of errors 0.77) and the memorised paper map (average number of errors 1.92). These findings are consistent with those of Streeter et al. (1985) and van Winsum (1987) in terms of the superiority of the verbal instructions. However as reported in Schraagan (1993) Verway highlights that the higher number of errors in the visual condition may have been due to the types of arrows use. These were all at 90 degree angles and thus participants expected the turnings to be 90 degree turnings which some were not.

Verway and Janssen (1989) also performed a second study looking at route guidance information. This study was a logical follow on to the previous study as information modality (auditory vs visual) and code (verbal vs spatial) were confounded, and the advantages of the auditory, messages may have been caused by either one. Twenty-six participants took part (all male aged between 20 and 40). Participants were required to perform a tracking task while indicating navigational choices on a keypad based on information presented either as auditory/verbal e.g. "Turn Left", or verbal visual e.g. a screen displaying the words 'TURN LEFT'. Visual/Spatial instructions consisted of perpendicular or straight arrows displayed on a screen. Looking at response times

Verway and Janssen (1989) found that auditory/verbal route guidance led to the best response, visual/verbal to slower responding and visual spatial to the slowest. However there was no significant difference between the auditory/verbal and the visual/verbal. Also even though the secondary task produced poorer tracking performance there was no difference between the presentation modes for tracking performance. Verway and Janssen (1989) concluded that the modality is of little importance in the presentation of route guidance instructions as long as simple instructions are used, and any visual information is accompanied by an auditory warning.

Labiale (1989) also investigated different displays of route guidance information these being an electronic map, map and auditory message, and a map with a written message. The electronic map was situated at steering wheel height on the dashboard and turned toward the driver. Text instructions were displayed below the map and auditory instructions were the same as the text. Sixty participants took part in the experiment aged 20 to 63. Two routes were driven of differing complexity for comparative purposes. Dependent measures for the experiment were visual glance data, route recall performance, preferences, and steering and speed variability. Labiale (1989) found that glance duration and frequency was least for the map with verbal instructions. Glance duration increased with map complexity. Drivers were found to prefer the map with verbal instructions present, though route recall was best for maps with text instructions. Labiale (1989) also found that the map display had an effect on driving performance. Drivers strategically slowed their driving when consulting the maps in order to compensate for the higher mental workload induced.

In a study investigating the use of road signs and left-right instructions Schraagan (1991) hypothesised that the more drivers can anticipate, the lower their mental workload. 42 participants took part in the study (half male, half female). The participants were required to drive three routes. The route guidance instructions were printed on cards and presented to the driver by the experimenter. There were three types of route-guidance instruction: left-right instructions in the form of arrows, road sign instructions such as 'take exit Amersfoot', and multiple instructions such as 'turn right, Galvanistraat; turn left; turn left, Leusderweg'. The multiple instructions resulted in more navigational errors than the other two conditions and the use of road sign information did not improve on the performance of the arrow instructions given. However Schraagan (1991) did not use a combination of arrows and road sign information which may have improved on the arrows alone situation.

The studies described so far have mainly looked at the performance of drivers in the navigation task when using route-guidance systems. However even if the performance of the system is good this does not necessarily make it safe. It is important to look at driver behaviour as well as performance. Fairclough, Ashby, and Parkes (1993) compared the use of a paper map with a simulated electronic navigation device aiming to look at driver behaviour in terms of visual 'cost' of using a navigation device. Twenty participants took part in the study (10 male, 10 female) between 20 and 60 years of age. The paper map was attached to card, which could be rotated, with the route marked in a green highlighter pen. For the electronic device text instructions presented as a list of navigation commands, were presented to the driver. Participants drove two routes using each of the navigation devices. The dependent measure was mean glance duration calculated from glance duration and frequency. Fairclough et al (1993) found an increase in visual attention to the map display at the expense of visual allocation to other areas of the driving scene. The other regions of the driving scene where attention was reduced, were the roadway ahead, the rear view mirror, and the right wing mirror.

Burnett and Parkes (1993) also looked at the different route guidance information presentation and their related safety. 16 participants took part in the experiment (8 male, 8 female; 75% under 30 years old), and were required to drive two routes receiving either visual instructions or a combination of visual and auditory guidance. The visual instructions took the form of symbols presented on a LCD computer screen, mounted centrally on the vehicle dashboard at a height of the steering wheel centre. The auditory instructions were recorded digitised speech consisting of simple messages. Half of the participants also received pre-information on making manoeuvres giving an approximate distance to the next manoeuvre. Dependent measures were time to complete the route, number and type of navigational errors, visual glance frequency, visual glance duration, and subjective indices of mental workload.

Results from the Burnett and Parkes (1993) study showed fewer glances and shorter duration glances when both the visual and auditory system was used, this also being the main preference of the drivers. The mental workload for this condition was also lower. The pre-information was found to be helpful but did increase the frequency and duration of glances. The study however only used simple auditory information and pre-information was only presented visually, and was sometimes confused with other types of visual information. Also the study did not compare the use of auditory instructions alone, though their simple nature may have made this impossible or an unfair comparison.

Burnett and Joyner (1997) carried out two field trials to evaluate the man-machine interfaces of three existing route guidance systems in terms of driver workload, behaviour and performance. In the first field trial, a moving map-based system was compared with maps/notes and standardised verbal instructions given by the experimenter. The latter two conditions were 'baseline' driving conditions. Sixteen male and eight female participants (aged 40-60) took part in the experiment and were required to travel pre-determined routes. Dependent measures used were journey time, navigational errors, visual attention and vehicle performance parameters. Subjective opinion, and workload measures were also taken. Negative aspects of the moving-map display were increased time to reach the destination when compared to verbal instructions, which could be related to the increased errors made with the moving-map display. It was, however, possible that drivers reduced their vehicle speed as a consequence of the increased task demands when using the systems (Burnett and Joyner 1997). The participants rated a lower workload score for the moving map than the map/notes but again the verbal instructions had the lowest workload. Participants also spent more time with their eyes off the road than with the maps/notes.

The second field trial compared two symbol based systems with the standardised verbal instructions used in the previous trial. Methods, participants and measures were also the same as the previous trial. One of the symbol based systems presented information late on approach to certain manoeuvres. The consequence of this poor timing was especially evident along the dual carriageway where participants were not able to get across to the inside lane and so missed the exit. Reduced road layout information by one of the systems promoted greater reliance on road street name information. Results of poor message timing were found to be late indication and late lane changes, resulting in dangerous driving behaviour. The most negative aspects coming from the three route-guidance systems tested in the trial was the increased time spent with the eyes off the road as compared with the baseline conditions. The use of voice instructions with the symbol based displays helped reduce the visual cost of the displays, compared with the map-based system. Use of all three route guidance systems significantly reduced the visual attention allocation toward the road ahead and the rear view mirror when compared to the verbal instructions.

Srinivasan and Jovanis (1997) conducted a simulator experiment to evaluate various route guidance systems including head-up displays. Head-up displays are not a focus of research in this chapter but the experiment is included, as all the other methods of presentation are relevant. Drivers navigated a network using five route guidance methods: paper map, head down turn-by-turn display, head-down electronic route map, head-up turn by turn display, and an audio guidance system. Seventeen participants between the ages of 19 and 35 took part in the experiment (gender unspecified). Participants drove five routes using each of the route guidance devices while simultaneously performing a scanning task which involved monitoring squares at the left and right hand side of the road for changes in shape. Dependent measures included navigational errors, subjective preference and performance in the scanning task. The number of errors was too low to be analysed. However for the scanning task, participants were found to be able to react faster with electronic devices than with the paper map. It was also found that they were able to react faster with the auditory system compared with the visual systems as this permitted drivers to look at the driving scene more often. However some participants reported the auditory system to be annoying and wished to have the option to shut it off. Another problem was that the information was only given at a specific point in time and not continuously updated as with the visual systems.

Eby and Kostyniuk (1999) compared system performance and driver opinion of 3 in-vehicle route guidance systems. Two of the systems were commercially available products (Ali-Scout and TetraStar) and consisted of a combination of symbol and spoken commands. The third system comprised of written instructions. 360 participants took part in the experiment (51.9% male) between the ages of 19 to 80 years (though age was not a focus of the study). Participants were assigned randomly to a route guidance system condition and asked to drive between the chosen origin and destination as quickly and as safely as possible. Dependent variables included subjective preference, navigation errors and trip duration. Few drivers in the study made navigation errors regardless of the system used. One of the commercially available systems (TetraStar) received the highest rating followed by the written instructions. The other commercially available system (Ali-Scout) rated poorly as it did not give turn by turn instructions at the beginning of the route. However both of the commercially available systems produced trips of a shorter duration than the written instructions.

The experiments thus far have looked at the presentation of information in terms of a general driver population. Even though participants in the higher age ranges have been used in some of the experiments comparisons of older and younger drivers have not been made in terms of performance, workload and behaviour. There have, however, been a number of studies which have looked at route guidance presentation and age. Wierwelle, Antin, Dingus and Hulse (1988) looked at the visual demands of an in-car navigational display as part of a field trial. Thirty-two participants took part in the study of both genders, and of all ages (18 to 73). Differences were found in the results between drivers over 50 years of age and those under 50 years of age. The older participants took more time to complete the tasks, looked at the navigation and dash instruments longer, and made a greater number of errors than the younger participants.

Walker, Alicandri, Sedney and Roberts (1991) tested seven navigational devices in a driving simulator, for their effects on safe driving performance. Participants were split into three age groups: younger (20-25); middle aged (35-40); older (55+). There were forty-two participants in each group who navigated a 26 mile route using one of the devices. A control group used strip maps and the other six used either an auditory or visual device, which was either low, medium, or high complexity. The workload placed on the driver was increased in three successive sections by adding crosswinds, another vehicle, narrowing of lanes, gauge monitoring and mental arithmetic problems. Dependent measures included speed, average of lateral placement, variance of lateral displacement, heart rate and reaction time to gauge changes. Walker et al

(1991) found that older drivers drove more slowly, had larger variability in lateral placement, and had longer reaction times to the gauge changes. Therefore they performed less safely (Walker et al1991). Also the older drivers were more likely to make more navigational errors than the other two groups. The effects of increased workload effected older drivers in terms of performance more than the other two age groups. In terms of the presentation of route guidance information participants using auditory guidance did not reduce their speed as much in high mental load situations and made fewer navigational errors. Also participants using the more complex devices drove more slowly than those using the other devices. The main difference between the medium and low complexity devices was the higher number of navigation errors made with the low complexity device. Overall the worst driving performance resulted from the complex visual device. The study by Walker et al (1991) did not however compare combinations of auditory and visual systems with visual only or auditory only. Walker et al (1991) also highlights the difficulty in recruiting older drivers and the high drop out rate of older drivers due to simulator sickness (>50%).

James and Ehret (1993) conducted an experiment investigating the use of perspective single intersection route guidance displays, as an approach to reducing attentional demand of older drivers. This was compared to a plan view which requires some mental rotation. Forty-eight participants took part in the experiment and were classed into age bands of young (mean age: 23), young old (mean age: 68) and older (mean age: 74). Participants were required to respond to whether the display matched a projection of an intersection. They found a preference for displays in the plan view (79%) over perspective view (21%) with the older drivers preferring the plan view more strongly. There was no significant difference in reaction time, but a higher accuracy was found for displays in the plan view. Explanations for this were the plan views familiarity (e.g. maps and road signs are in plan) and the third dimension of the perspective view i.e. depth may increase the processing required. The task was static and James and Ehret (1993) question whether these results would stand when performing a dynamic task.

Pauzie and Anadon (1993) conducted a study in a simulator aiming to evaluate the efficiency of various information presentation modalities. The route-guidance was in the form of arrows displayed on a screen combined with preparatory beeps or verbal instructions. Ten younger participants (mean age of 25 years) and ten older participants (mean age of 60 years) took part in the study. The participants task was to drive a route following the guidance instructions. Dependent measures were visual behaviour and subjective preferences. They found that older drivers had higher glance frequencies towards the visual display than younger drivers. When the verbal messages were used this produced less visual checking of the route-guidance screen for both groups of drivers and in many cases the information provided was sufficient for the screen not to be checked at all. Preparatory beeps were considered annoying by many of the drivers. Pauzie and Anadon (1993) concluded that the most preferable presentation would be a combination of verbal and symbol-based visual presentation. Even thought they did not test the verbal guidance on its own, this was not seen as the optimal solution due to vehicle noise.

Wochinger and Boehm-Davis (1997) compared four navigational aids using both younger (28 participants; 30-45 years; equal gender) and older drivers (28 participants; 65-75 years; equal gender). The experiment utilised a part task simulator, and participants were required to perform a tracking task while making navigation decisions using a directional keypad. The four navigation aids were a simulated turn-by-turn display (ATIS display), a standard street map, a big paper map, and text directions. Dependent measures included decision time and error rate. Navigational preferences were also sought through the use of a questionnaire. They found that older drivers generally made more errors and took longer to make decisions at choice points. The ATIS display and text directions caused less errors than other displays for older drivers, and the ATIS display produced the fewest errors for younger drivers. The ATIS display and text directions produced the quickest response time for both groups of drivers. Wochinger and Boehm-Davis (1997) also found that drivers are aware of the navigational aid most suitable to them. Generally drivers performed better with the type of navigational aid they preferred, e.g. persons who preferred maps did better in that condition than those who did not prefer maps. However, regardless of their initial preference, navigational performance was typically better with the ATIS display. Further to this the older driver group rated maps more highly than the younger driver group, indicating perhaps that the older drivers may not wish to give up their use of maps. The experiment however did not utilise voice guidance which may have changed driver preferences and did not look at the safety aspects of the display.

Finally Lansdown and Burns (1997), in recognition of the need to make comparisons for auditory only displays, conducted a simulator experiment to compare auditory only, visual only, and a combination of the two media. The main aim was to identify the best way to present simple route guidance instructions to drivers across ages. The visual instructions consisted of simple left and right arrows placed just outside the steering wheel, and the auditory instructions employed a digitised female voice, giving instructions of 'next left' or 'next right'. Twenty-four participants took part in the experiment (15 male, 9 female), with ages ranging from 18 to 69. Dependent measures were navigational errors, visual glances away from the forward view (duration and frequency), and subjective mental workload. Subjective mental workload was highest for the visual only condition with no significant difference between the auditory alone and the visual-auditory combination. The number of navigational errors was also highest for the visual only condition along with glance duration and frequency. The use of auditory information with the visual information was found to significantly reduce the number of glances away from the forward view. Subjective preference was found to be highest for the visual-auditory combination.

Even though the experiment was aimed at looking at presentation across ages, only three of the participants were classed as elderly (>60 years). The original sample, had more older drivers, as two of the first five older participants were unable to complete the experiment due to feelings of nausea (a problem also highlighted by Walker et al 1991). Lansdown and Burns (1997), because of this, stopped the recruitment of the older drivers on ethical grounds.

7.3 Discussion of literature

The above studies can be seen to vary in the individual modes studied (visual/auditory) and combinations of the two. The studies have also looked at different presentation designs e.g. maps and directional systems, and the effects of age on performance, mental workload and driver behaviour. Table 7.1 summarises the studies.

Table 7.1: Summary of literature on Route-Guidance Display Methods

Study	*Auditory*	*Visual*			*Auditory/Visual Combination*	
	Speech	Text	Maps	Symbols	Speech & Maps	Speech & Symbols
Streeter et al (1985)	✓*		✓		✓	
Van Winsum (1987)	✓*		✓			
Verway & Janssen (1988)	✓*			✓		
Verway & Janssen (1989)	✓*			✓		
Labiale (1989)			✓		✓*	
Schraagan (1991)		✓		✓*		
Fairclough et al (1993)		✓*	✓			
Burnett & Parkes (1993)				✓		✓*
Burnett & Joyner (1997)	✓		✓	✓		
Srinivasin & Jovanis (1997)	✓*		✓	✓		
Eby & Kostyniuk (1999)		✓				✓*
Wierwelle et al (1988) ✦			✓			
Walker et al (1991) ✦^	✓*		✓	✓		
James & Ehret (1993) ✦^				✓		
Pauzie &Anadon (1993) ✦^				✓		✓*
Wochinger & Boehm-Davis (1997) ✦^		✓	✓	✓*		
Lansdown & Burns (1997) ✦	✓			✓		✓*

✦studies with older drivers

^differences found between older and younger drivers

* best presentation method

Table 7.1 presents the main findings from the literature. The column titled 'maps' encompasses both the electronic form and paper form. Also the table does not highlight all of the combinations used (e.g. text and maps), but does cover the main findings. The study by Wierwelle et al (1988) did not look at route guidance but navigation using an electronic map compared to a paper map and so has no specified best system (there was no difference found anyway), and is included as it did look for differences across ages. Also the study by James and Ehret (1993) was looking at perspective vs plan view for symbols and is again included for its relevance to visual presentation and differences across ages (plan view better performed than perspective). The study by Srinivasan and Jovanis (1997) included the head-up displays, not forming part of this research, but head-down displays were also employed, and so is relevant to the work.

7.3.1 Display Presentation

The main presentation methods reviewed in the literature were visual, auditory and a combination of the two. The presentation methods for each of the modalities and their usefulness for route-guidance in terms of safety and performance are discussed in this section.

Visual Modality

Maps

From the literature it can be seen that maps are generally a poor means of route guidance, either in the form of an electronic map or a paper map, the study by Wierwelle et al(1988) finding no difference between the two. As can be seen from table 7.1, all other methods when compared with maps were preferable in terms of performance and safety. Even though maps provide most of the information for navigation e.g. overview of the route, distances, junctions, road names/numbers etc. this is generally too much information whilst driving. Some drivers also have trouble understanding the spatial relationships presented on maps (Brown 1993). The driver is left to try and select the most relevant information depending on the driving circumstances, which can lead to a long processing time, and the driver taking their eyes off the road for unacceptable periods of time (Wierwille et al 1988; Ashby et al 1991; Brown 1993). Much of the information is not directly relevant for route-guidance purposes (Schraagan 1993), and so need not be presented.

Text

Only four of the studies used text as a presentation method. In the study by Fairclough et al (1993) in which text was compared with maps, the text presentation method was superior. However the other studies using text have shown this to be inferior to other methods of presentation. Essentially text messages need to be read and understood, in order to respond correctly. The process of reading and understanding in terms of a task competing with driving, will take up much processing time.

Symbols

Many of the studies used symbols for the visual presentation. Symbols have been shown to be superior over maps e.g. Wochinger and Boehm-Davis (1997) and text e.g. Schraagan (1991); Wochinger and Boehm-Davis (1997). Symbols, if well designed, makes for quicker perception and processing, and only that information which is needed by the driver is presented. This means displays can be very simple, which is beneficial as demonstrated in the studies by James and Ehret (1993) and Labiale (1989), where an increase in the complexity of the display led to a decrease in performance. This in terms of the visual modality is the superior design for information presentation. However symbols alone are not the overall best method of route guidance presentation.

Auditory Displays

Speech

Nearly all of the studies using auditory displays used speech. Beeps were also used in some of the studies to alert the driver to visual information, but were generally found to be annoying. In nearly all of the studies where speech alone has been used as a route guidance method it has proved superior to nearly all other methods i.e. maps, text, and symbols. As mentioned in the introduction, driving is primarily a visual task, and so competing visual tasks can lead to distraction, whereas the auditory channel is not yet loaded (Brown 1993). Allocating secondary tasks such as route-guidance to the auditory modality can, therefore, allow for easier cognitive processing, making the driving task safer and easier. Also auditory commands are temporal, and so can be given at the relevant point in time e.g. 'turn now'. It must however be recognised that auditory messages do require cognitive attention and so can still lead to distraction.

Combination Displays

Speech and Maps

Two of the studies combined modalities, using speech and maps. The study by Labiale (1989) showed the combination of speech and maps to be superior to the use of maps alone. However the study by Streeter et al (1985) showed that the use of speech alone was superior over maps alone and the two combined. It seems in the study by Labiale (1989) the advantage of the speech/map combination, was due to the speech alone and not a combination of the two i.e. simply using the speech would have produced the advantage. Using a map display when speech is present will have a detrimental effect, as all the problems associated with map displays will still be present.

Speech and Symbols

Four of the studies combined modalities, using speech and symbols. The study by Eby and Kostyniuk (1999) showed this combination to be superior to written instructions. In the studies by Burnett and Parkes (1993) and Pauzie and Anadon (1993) a combination of speech and symbols was superior to symbols alone. However these studies did not compare the combination to speech alone which itself has been shown to be superior to the use of symbols. The only study comparing these three methods was that by Lansdown and Burns (1997). Here the combination of speech and symbols was found to be superior over speech alone and symbols alone. It seems by combining the two the advantages of both methods is attained and disadvantages of each overcome.

7.3.2 Age

Only six of the studies looked at differences across age. The study by Lansdown and Burns (1997) intended to look at differences between older and younger drivers but simulator sickness in the older driver group (a problem also found by Walker et al (1991)) meant recruitment was stopped. The low number of older drivers used meant comparison across ages was not feasible. The use of simulators appears to be a problem when studying older drivers. Differences however were found in the five other studies. Main areas of difference in using the route-guidance systems for older drivers as compared to younger drivers, appear to be

- driving more slowly (Wierwelle et al 1988; Walker et al 1991)
- looking at the route-guidance instrument for longer periods of time (Wierwille 1988)
- looking at route-guidance display more frequently (Pauzie and Anadon 1993)
- longer decision making times (Walker et al 1991; Wochinger & Boehm-Davis 1997)
- more navigational errors (Wierwille et al 1988; Walker et al 1991; Wochinger & Boehm-Davis 1997)
- more susceptible to decreased performance due to higher workloads (Walker et al 1991)

These findings have only come from a small number of studies, and thus are not conclusive. The study by James and Ehret (1993) produced one further finding for older drivers in that plan view symbols are preferred to perspective view, with this preference being stronger for older drivers.

The differences found for older drivers, in the main are a result of using visual displays. Indeed, the studies by Wierwille et al (1988), James & Ehret (1993), and Wochinger & Boehm-Davis (1997) only used visual displays. However it can be seen that the best methods of presentation are either through speech or a combination of speech and symbols. Only the study by Lansdown and Burns (1997) has made a direct comparison between these two methods over all of the studies covered in the literature review (speech & symbols combination performing the best). However due to the low number of older drivers used age differences could not be studied. Therefore the problems identified for older drivers are problems which may be overcome through the best presentation of route-guidance information.

7.4 Conclusions

From the literature it can be concluded that symbols are the best design for visual presentation and speech for auditory presentation. Of the two, speech is the preferable method of route-guidance presentation. However when speech and symbols are combined this may be the preferred presentation method. Only one study (Lansdown and Burns 1997) has compared speech, and speech and symbols combined. In terms of older drivers there are a number of problems with visual screens being present e.g. distraction caused, which has a greater effect than on younger drivers and thus threatens safety. The study by Lansdown and Burns(1997) did not compare speech and the combined speech and symbols across ages, due to simulator sickness in the older drivers. This requires further research. Also the route guidance used in the Lansdown and Burns (1997) study used very simple information i.e. left-right instructions only. A system designed on information needs of drivers and timings (identified in earlier chapters), may also help reduce the problems for the older drivers.

Chapter 8: Study 2 Methodology

8.1 Chapter Summary

This chapter introduces a laboratory experiment, which was conducted to identify the best modality for the presentation of route guidance information across ages. The focus of the chapter is the methodology employed, covering sampling, experimental design and procedures. The reasons for choosing a lab based trial are highlighted and a detailed description of the computer tasks and display of the route guidance information given.

8.2 Introduction

The previous chapter covered issues on the best modality for information presentation and the best design for these presentation modes. Concerning the design it was established that for auditory modes speech was the most appropriate method of information presentation. For visual screens symbols were the most appropriate method of information presentation. However the issue of how these two modalities should be used (e.g. auditory only, visual only, auditory and visual combined), was not entirely resolved. Current literature indicated that the best modality was either auditory alone or a combination of auditory and visual information. However studies in this area are not conclusive. Also very few of the studies used age as a factor in deciding the most appropriate presentation modality.

Only one study (i.e. Burns & Lansdown 1997) has compared the auditory alone modality (using speech) with a combination visual-auditory modality (using speech and symbols). Age was originally part of this study but comparisons were not possible as many of the older drivers had to drop out due to simulator sickness. Also the content of the information was based on directional information alone.

The lab based study introduced in this chapter investigated the effectiveness different modalities (i.e. visual only, auditory only, visual-auditory combination). These were based on speech and symbols design. The aim was to identify the most appropriate method of presenting the route guidance system information identified in chapter 6 to drivers across ages. By using the content and timing of information identified in chapter 6 this would also provide an initial validation of those recommendations.

8.3 Method

8.3.1 Experimental Design

The experiment was of mixed design with age as the between participant factor and condition (modality of presentation: visual, auditory, and visual/auditory) as the within subject factors. Dependent variables were number of errors made by participants and subjective workload tests. Independent variables were age and condition. The experiment was counterbalanced across age, gender and condition.

8.3.2 Sampling

Participants were recruited from an existing database. Persons on the database had previously been recruited mainly through the use of adverts taken out in a local paper. The field trial required both older and younger drivers for comparative purpose. The profile which the participants had to adhere is presented in table 8.1.

Table 8.1: Participant requirements

Criteria	*Older Drivers*
Age	Older Drivers - Over 55, ideally over 60
	Younger Drivers 19 - 35
Health	In good health
Licence	Held a driving licence.

As with the field trial (see chapter 4) the age for older participants was put at 55+ years but ideally 60+years as 55 is the general point at which the ageing process will degrade driving performance (Planek 1981). To try and make sure this driver group was captured the ideal age was 60+ years which is five years on from when the age declines begin to become apparent. Ideally it would have been appropriate to observe age groups in older age ranges than this but due to time and money this was not practical. Anyone over the required age was grouped together under older drivers. The younger drivers had to be between 19-35 and hold a driving licence. The requirements were not as strict as the field trial as participants would not be required to drive a car. The reason that both groups of drivers were required to be in good health was that the focus was in the navigation strategies of older drivers with any declines in abilities coming through the ageing process and not through any illness.

8.3.3 Participants

Twenty four participants took part in this experiment. 12 were older drivers (6 male, 6 female) and 12 were younger drivers (6 male, 6 female). The average age of the older male participants was 62 years (SD 3 years) and 60 years (SD 3 years) for the older female participants. For the younger drivers the six male participants had an average age of 26 years (SD 4 years) and the female participants had an average age of 25 years (SD 2 years).

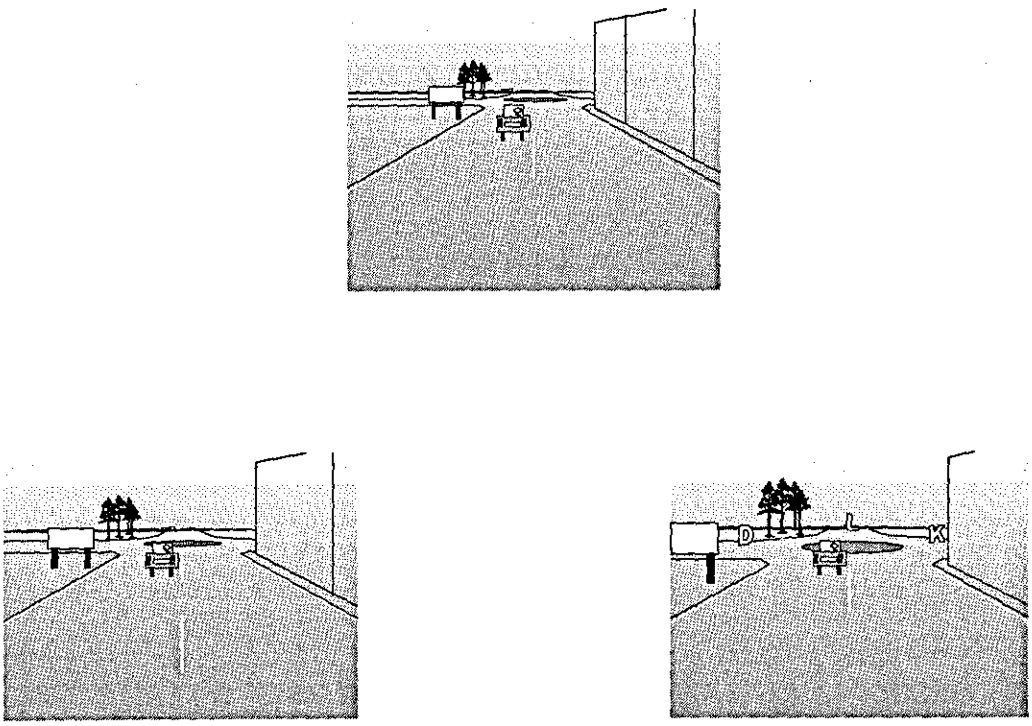
8.3.4 Apparatus

The testing of the navigation system and various modalities of its use meant that it would not have been ethical to run as a field trial. Also due to a high rate of driving simulator sickness amongst elderly drivers (Walker et al., 1991; Ward and Parkes 1996, Lansdown and Burns 1997) it was not cost effective or ethical to use such equipment either. As an alternative a PC based driving environment was developed using PowerPoint which aimed to model the driving task in terms of a car following exercise and navigational decision making. The PC model consisted of a moving forward view of the road in front. The visual scene was a mixture of urban and rural environments, consisting of junctions other traffic and landmarks. The development is described below.

The PC Model

Using Powerpoint roadway scenes were drawn onto slides. Each of the slides was treated as and animation frame. Groups of frames were drawn depicting different road scenarios e.g. travelling along a straight road, junctions, bends in the road (see figure 8.1).

Two slides used to depict rural road



Example of three slides drawn to depict the run up to a junction

Figure 8.1: Examples of two groups of frames drawn to depict different road situations

By running and repeating groups of frames using custom slide show facilities the animation effect was produced. For example the two frames for a straight rural road can be repeated many times to produce roads of different lengths at the end of which the group of junction frames could be added. All in all 94 slides were drawn forming groups of frames which made up the environmental features including

- Urban roadway environments
- 2 different rural roadway environments
- 8 different roundabout scenarios (set in urban and rural environments)
- 3 different t-junctions scenarios (rural and urban environments)
- 4 different other junction type scenarios (with traffic lights in urban environments)
- 6 different side road scenarios (in urban and rural environments).

With these different road types/ junction types available it was now possible to plan routes, and then build them using the groups of frames ordered as required. Three routes were built up each designed to have various combinations of road environments. Each of the routes was identical in their make up of slides but the orders were different. Each of the routes contained the 42 decision points the breakdown of these along with the junction types are shown in table 8.2.

Table 8.2: Breakdown of the decision points encountered along each of the routes

Junction Type	*Number of Junctions*	*Straight on*	*Left Turns*	*Right Turns*
Roundabouts	8	4	2	2
Cross-roads	6	3	0	3
T-junctions	4	0	2	2
Side Roads	24	20	2	2
TOTAL	42	27	6	9

Each of the routes required approximately 2000 frames (slides) to run on the computer. Each route ran at a frame rate of approximately 3 frames/ second. The routes were run at this rate and did not stop at any point until the end and took approximately 12 minutes to complete.

The Tasks

This road environment allowed two tasks to be developed for the testing of the navigation system.

The Primary Task

The primary task was a car following exercise. On the screen incorporated into all of the slides was a lead vehicle. This would periodically brake moving towards the bottom of the screen (see figure 8.2).

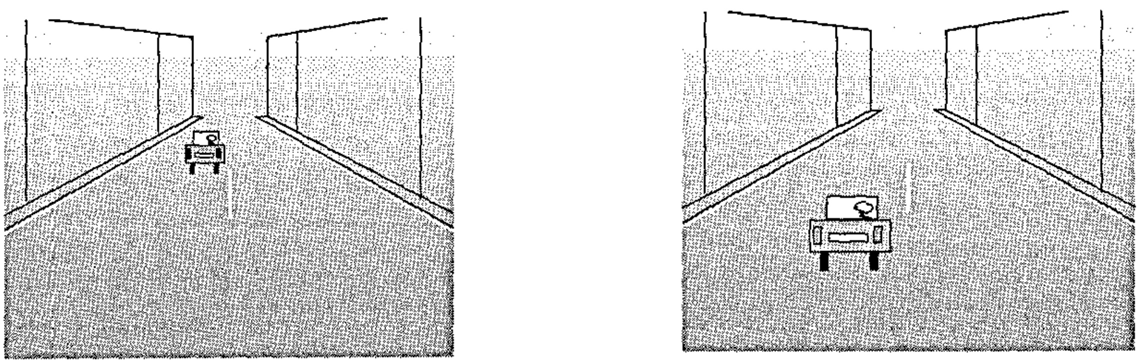


Figure 8.2: The first slide shows the lead car as normal. The second slide shows the lead car has braked

When this happened, the response required was to press the Space Bar of a computer keyboard (i.e. braking your car). For the car to move to the bottom of the screen required two frames (a time of 0.66 seconds) for which to make a response. If no response was made then the car would automatically move back anyway and an error recorded.

This exercise was chosen as it required the participants to constantly monitor the screen in front of them, which was there to model the concentration and attention required in the driving task.

The Secondary Task.

For each of the junction scenarios, a letter was placed on each of the possible roads which could be taken (see figure 8.3).

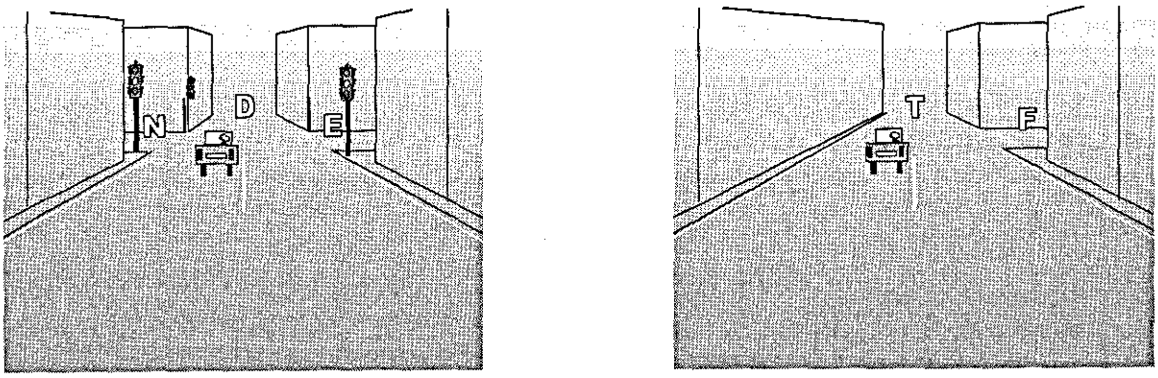


Figure 8.3: Each junction had a letter placed on each of the choices which could be made at that point

Each junction required three frames (each moving closer to the junction). The letter was only displayed on the last frame, which meant it 'flashed' up on the screen for a period of 0.33 seconds. The letters were displayed to allow the participants to make navigational decisions by telling the experimenter the letter of the road they wished to take. The letters displayed changed from junction to junction, so participants wouldn't be able to pre-empt or memorise letters. Also the letters were chosen so as not to have any associations e.g. 'L' for Left or 'R' for right. This was done so the participants would actually have to see the letters in order to choose the appropriate one. This method again ensured that participants would have to continually monitor the screen in front of them, so as to see the letters and then make the correct choice based on navigational information provided by a second computer.

8.3.5 Presentation of Route Guidance Information

The presentation of navigational information was conducted using a laptop computer. Again Powerpoint software was used for these purposes. The information provided was based on the models developed for the content and timing of information, and literature/ current systems research. The presentation took two formats, visual and voice, each of which provided the same information at the same times and were designed to work together as well as independently.

Visual Presentation

The visual screen was situated 300mm to the left of the main monitor at and angled towards the driver. The visual information consisted of direction, junction layouts and distances (see figure 8.4).

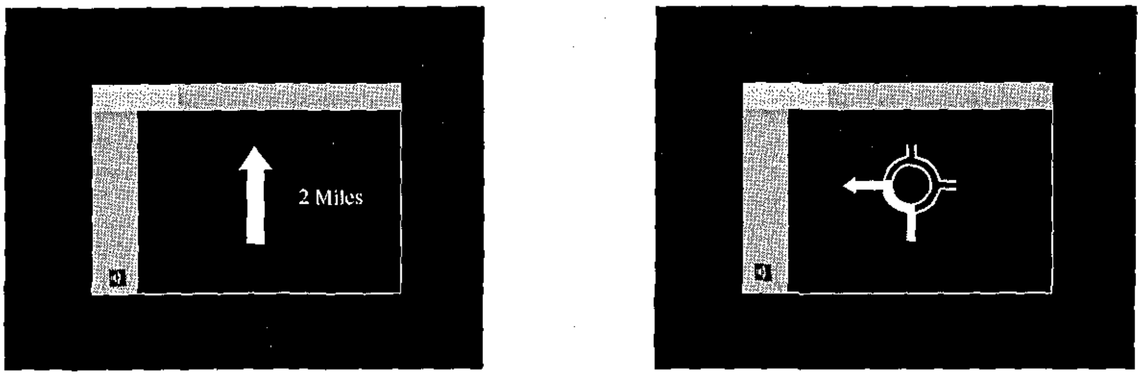


Figure 8.4: Examples of visual information presentation

The background screen was black in colour with a smaller screen drawn on measuring 170mm by 115mm. Within this was a main presentation screen which was dark blue in colour and measured 145mm by 100mm. All information displayed here e.g. arrows, distances were white in colour. The display visual information was set up to run in time with the computer generated route described earlier.

Voice Information

For the presentation of auditory information a recorded digitised female voice was used. The content and timing of the voice instructions was taken again from the recommendations in chapter 6. Each instruction was designed to run in time with the visual information and independently. Also as with the visual information it would run in time with the computer generated routes.

8.3.6 Procedure

Participants were given a set of instructions which explained the tasks to them and what they were expected to do, and given a training session to familiarise themselves with the car following and navigation tasks. Participants were then introduced to the second computer and an example of the both the voice and visual instructions was shown to them. Three methods of presenting the navigational information were employed: Visual, Auditory and Visual-Auditory. There were three different routes each being identical in their make up i.e. same junctions, road distances, turns. Each route took approximately 12 minutes to travel. All participants travelled the 3 routes and the order of presentation was counterbalanced across conditions. The experimenter recorded navigational errors (wrong letter selection), missed navigational decision points (failure to select a letter), and car following errors (failure to press space bar when lead car braked). The experiments were video recorded as a back up. Workload measures were obtained after each condition using the NASA R-TLX workload scales, along with ratings and subjective views of the navigational information presented (see appendix 2). At the end of the experiment a second questionnaire was administered to establish subjective preferences and some background information (see appendix 2).

Recorded information was then entered into a spreadsheet in order for the experimental analysis to be carried out.

8.4 Chapter Conclusions

This chapter presented the methodology for a study aimed at establishing the most suitable way to present route guidance information to drivers across ages. The experiment was lab based and carried out using a computer car following task as a simulator experiment was not possible due to a high level simulator sickness in older drivers. Drivers performed the car following task while being presented route guidance information from a second computer. The content and timing of the route guidance information was based on the recommendations made in chapter 6. The presentation of the information was based on information from the literature review in chapter 7. Participants drove three routes receiving either visual route guidance information, auditory route guidance information, or a combination of the two. Each time a decision point was encountered drivers chose a letter displayed on the main screen to indicate the direction of the turn they wished to take. Performance measures in terms of errors made while performing the task (both car following errors and navigation errors), were taken along with mental workload measures and subjective preferences.

Chapter 9: Study 2 Results

9.1 Chapter Summary

The results are presented in three sections. The first section deals with performance measures, the second subjective workload measures (NASA R-TLX) and the third section looks at subjective ratings for the content, timing and presentation of information. Data were analysed using ANOVAs for mixed design (Repeated Measures General Linear Models in SPSS) across condition and age. Previous research had not highlighted any gender differences and so this was omitted from the analysis. Post-Hoc analysis using Fishers LSD test were performed on data where there was a significant main effect of condition.

9.2 Performance measures

Three performance measures were recorded which were:

- Car following errors
- Missed junction errors
- Navigation errors

Each of these are dealt with separately in this section looking at both differences across age and condition

9.2.1 Car following errors

The car following errors was a measure of how many times the participant failed to respond to the lead car braking (the response being to press the space bar on the computer keyboard). Table 9.1 shows the mean number of errors with the standard deviation.

Table 9.1: Mean Car Following Errors (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	4.9 (2.4)	1.6 (1.6)	2.6 (1.6)
Younger Drivers	2.3 (1.3)	0.7 (0.9)	1.3 (0.9)

Due to heterogeneity of variance, transformations (as recommended by Howell 1997) were carried out on the data prior to the analysis of variance (using transformation Y= $\sqrt{(X+0.5)}$). There was a main effect of age [$F(1,22)=8.733$, $p<.01$] with older drivers having a higher error rate than younger drivers. There was a significant main effect of condition [$F(2,44)=39.396$, $p<.001$] with the highest error rates in the visual condition and the lowest in the auditory condition. There was also and interaction between condition and age [$F(2,44)=5.803$, $p<.01$]. Examining simple effects revealed that there were significant differences between older and younger drivers for the visual only condition and the combined condition, but not the auditory only condition. Figure 9.1 displays the mean errors across age and condition illustrating the differences highlighted (using original data).

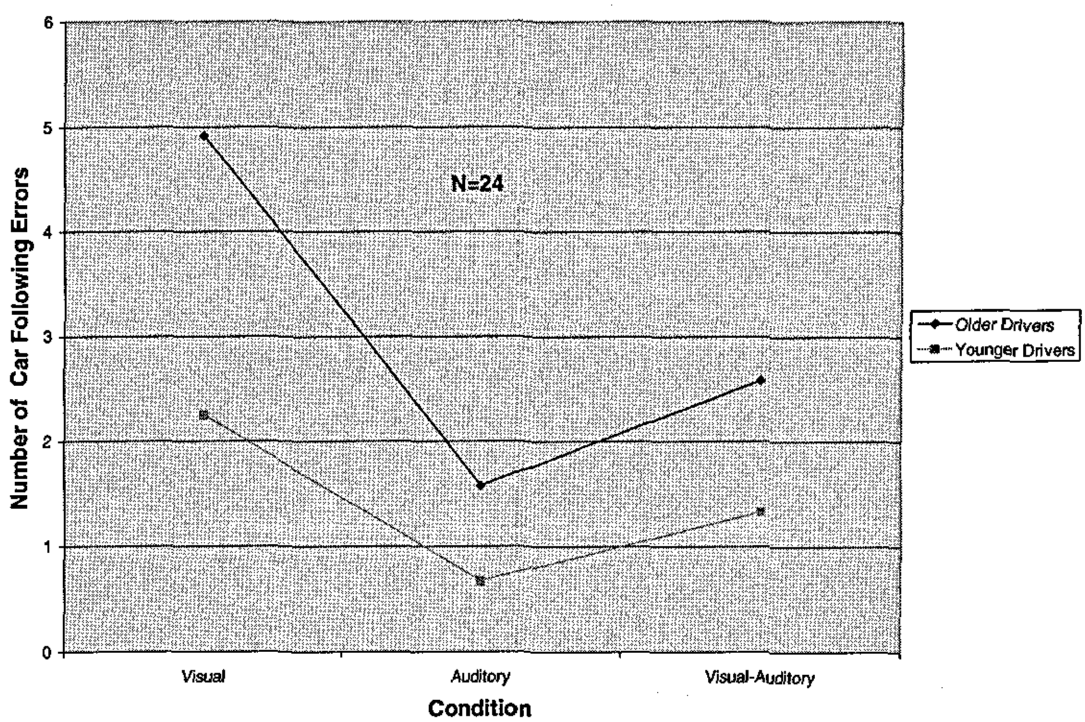


Figure 9.1: Mean Car Following Errors across Age and Condition

Post-hoc analysis of the condition effects (using original data) are shown in table 9.2. The visual condition produced significantly more car following errors than either the auditory or visual-auditory condition and the visual-auditory condition produced significantly more errors than the auditory condition.

Table 9.2: Mean car following errors for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Car Following Errors	3.6(2.3) A	1.1(1.4) B	2(1.4) C

***Means with the same letter are not significantly different (α=0.05)**

9.2.2 Missed Junction Errors

Missed junction errors were a measure of the number times the participant failed to give a letter at a decision point. Table 9.3 shows the mean number of errors with standard deviation.

Table 9.3: Mean Number of Missed Junction Errors (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	4.3 (2.5)	2.1 (1.7)	2.7 (2.1)
Younger Drivers	1.0 (1.4)	0.3 (0.5)	0.6 (1.2)

Again due to heterogeneity of variance a transformation was carried out on the data prior to conducting the Analysis of Variance (using $Y= \sqrt{(X+.05)}$ as recommended by Howell (1997)). There was a main effect of age [$F(1,22)=48.815$, $p<.001$] with the older drivers having a higher error rate than younger drivers. There was also a main effect of condition [$F(2,44)=4.399$, $p<.05$] with the visual only condition having the highest error rate and the auditory only condition having the lowest. Figure 9.2 displays the mean errors across age and condition.

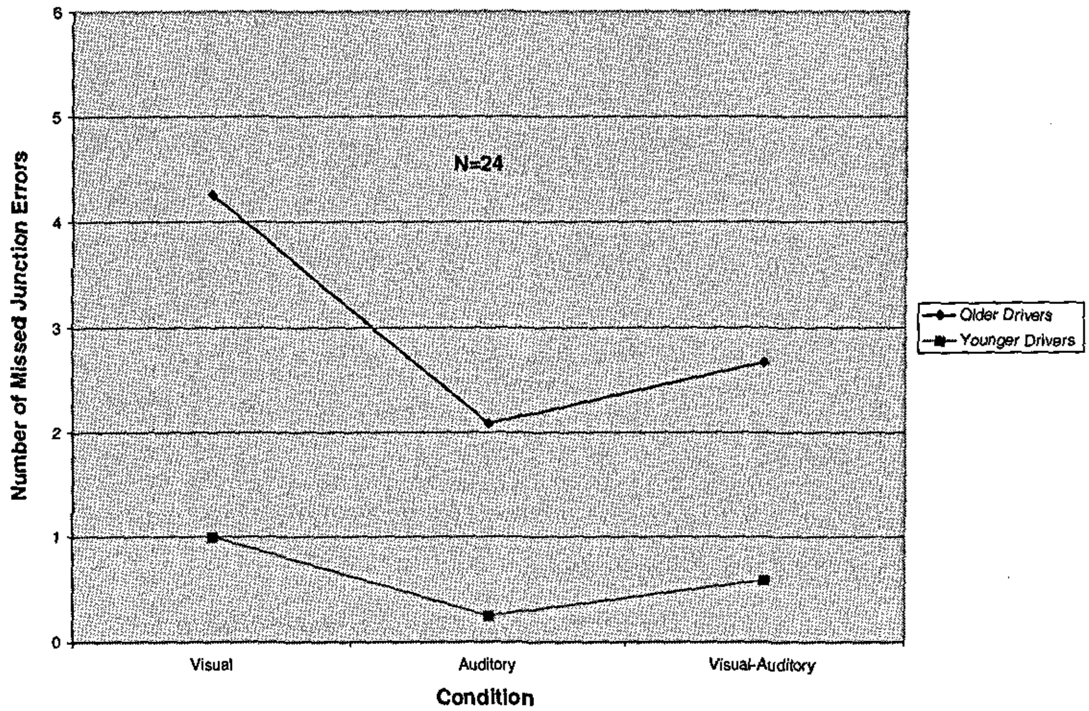


Figure 9.2: Mean Missed Junction Errors across Age and Condition

Post-hoc analysis of the condition effects (using original data) are shown in table 9.4. There was a significant difference between the visual only condition and the auditory only condition but no significance between the visual and visual-auditory conditions or the auditory and visual-auditory conditions.

Table 9.4: Mean missed junction errors for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Missed Junction Errors	2.6(2.6)	1.2(1.6)	1.6(2.0)
	A	B	AB

***Means with the same letter are not significantly different (α=0.05)**

9.2.3 Navigation Errors

The navigation errors were a measure of the number of times a participant chose the wrong letter at a decision point. Homogeneity of variance meant that no transformation of data was required. Table 9.5 shows the mean number of errors made along with the standard deviation across age and condition.

Table 9.5: Mean Number of Navigation Errors (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	2 (0.9)	0.3 (0.5)	0.7 (1.0)
Younger Drivers	0.3 (0.5)	0.2 (0.4)	0.3 (0.6)

There was a significant main effect of age [F(1,22)=16.090, p<.01], with older drivers making more incorrect letter choices than younger drivers. There was also a significant main effect for condition [F(2,44)=15.099, p<.001]. Figure 9.3 displays the mean errors across age and condition.

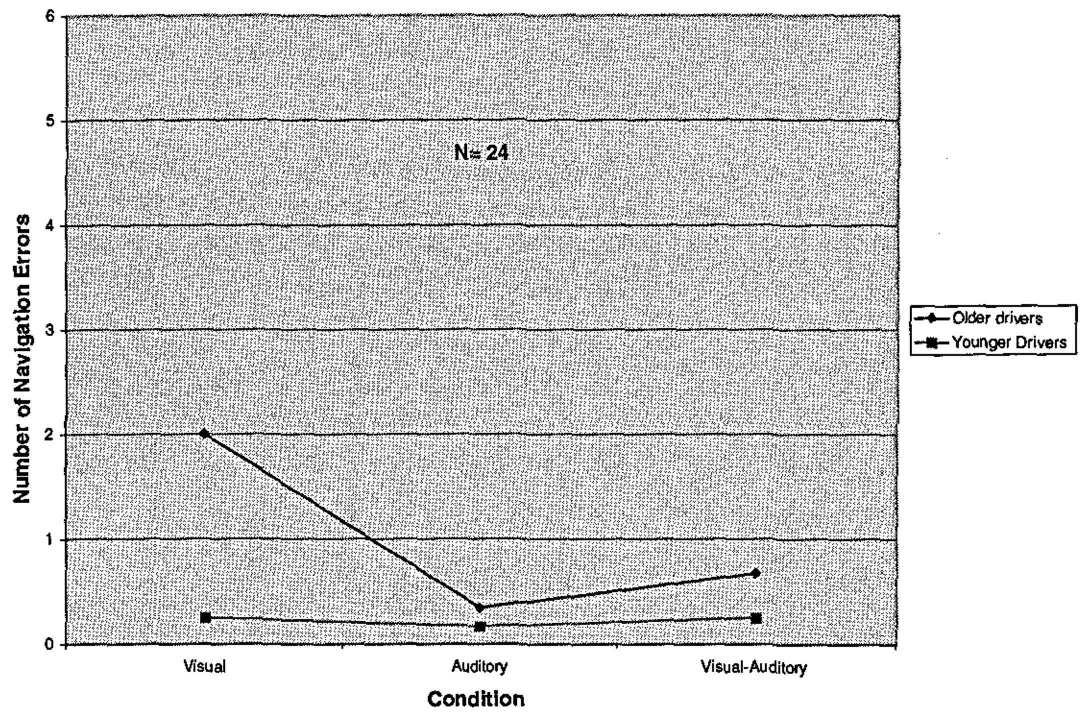


Figure 9.3: Mean Navigation Errors across Age and Condition

There was also a significant interaction between age and condition [F(2,44)=13.091, p<.001] which can be seen in figure 9.3. Examining simple effects revealed a significant difference between older and younger drivers in the visual condition [t(22)=6.280, p<.001] but no differences for the other two conditions.

Post hoc analysis of the condition effects (as there was a main effect of condition), are shown in table 9.6. The visual condition had a significantly higher error rate than the auditory and the visual-auditory conditions. There was no significant difference between the auditory and visual-auditory conditions.

Table 9.6: Mean navigation errors for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Navigation Errors	1.1(1.1) A	0.3(0.4) B	0.5(0.8) B

***Means with the same letter are not significantly different (α=0.05)**

9.3 Subjective Workload Measures

There were six subjective workload measures taken, which were:

- Mental Demand
- Mental Effort
- Physical Demand
- Time Pressure
- Distraction
- Stress Level

Each of the measures was rated on a continuous scale from 0 to 10. The six measures were each analysed independently and also a mean score over the six categories was taken to provide an overall workload score. Each of these measures are dealt with in the following sections looking at differences across age and condition.

9.3.1 Mental Demand

This was a measure of the perceived mental demand placed on the participants by the tasks being carried out. Table 9.7 shows the mean mental demand subject ratings across age and condition.

Table 9.7: Mean Mental Demand Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	7.0 (2.8)	4.6 (2.4)	4.1 (2.3)
Younger Drivers	6.0 (3.1)	4.3 (3.0)	3.6 (2.6)

There was no significant main effect of age but there was a significant main effect for condition [$F(2,44) = 12.038$, $p<.001$]. Figure 9.4 displays the mean mental demand scores across age and condition.

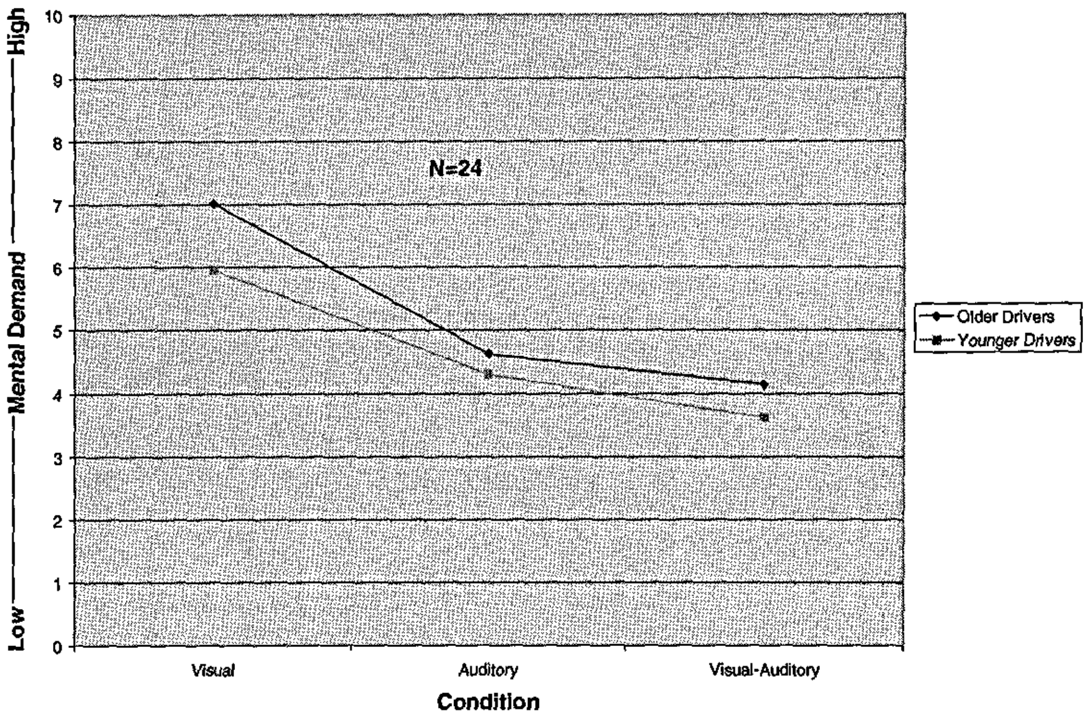


Figure 9.4: Mean Mental Demand Scores across Age and Condition

Post-hoc analysis of the condition effects, are shown in table 9.8. The visual condition produced a significantly higher mental demand than the auditory and the visual auditory conditions for which there was no significant difference.

Table 9.8: Mean Mental Demand Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Mental Demand	6.5 (2.9) A	4.5 (2.7) B	3.9 (2.4) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.2 Mental Effort

This was a measure of the perceived mental effort required by the participants performing the tasks. Table 9.9 gives the mean subjective ratings, along with standard deviations for mental effort, across age and condition.

Table 9.9: Mean Mental Effort Subjective Rating (standard deviation)

	Visual	Auditory	Visual-Audio
Older Drivers	7.0 (2.8)	4.8 (2.8)	4.4 (2.4)
Younger Drivers	6.3 (2.7)	4.7 (3.0)	4.1 (2.4)

There was a significant main effect of condition [F(2,44) = 11.440, p<.001] but no significant difference for age. Figure 9.5 displays the mean scores across for mental effort across age and condition.

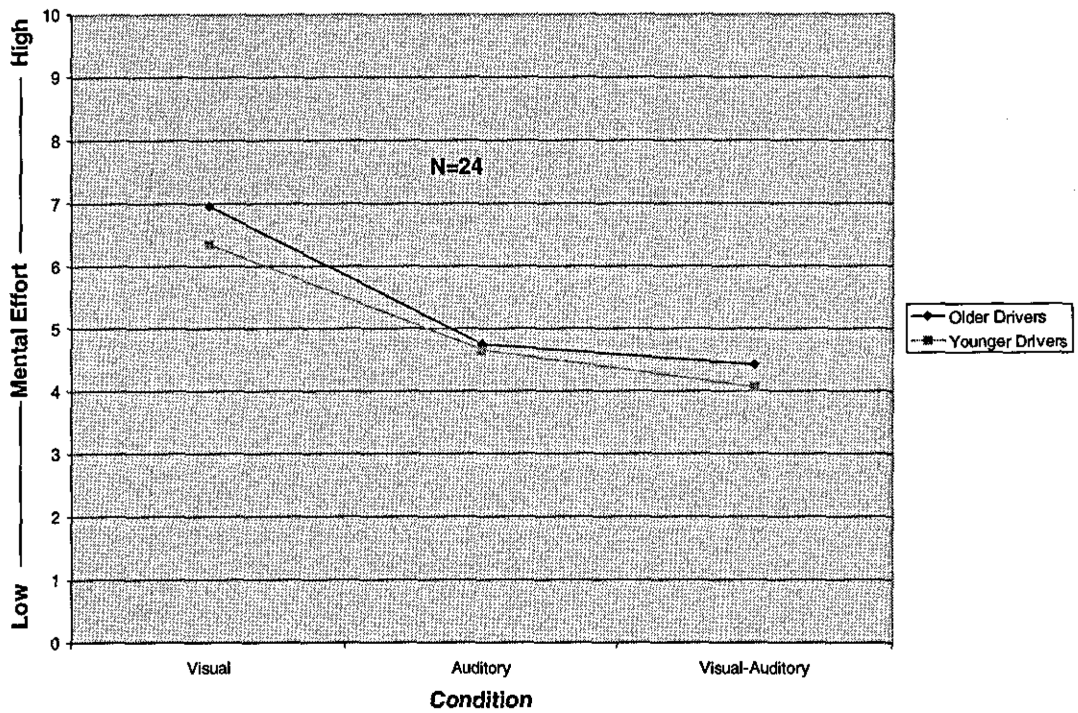


Figure 9.5: Mean Mental Effort subjective ratings across age and condition

Post-hoc analysis of the condition effects are shown in table 9.10. The visual condition had a significantly higher rating than the other two conditions. There was no significant difference between the auditory and the visual auditory conditions.

Table 9.10: Mean Mental Effort Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Mental Effort	6.7 (2.7) A	4.7 (2.9) B	4.2 (2.3) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.3 Physical Demand

This was a measure of the perceived physical activity endured by the participants when performing the tasks. Table 9.11 gives the mean subjective rating scores for this measure across age and condition along with the standard deviation.

Table 9.11: Mean Physical Demand Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	4.7 (2.5)	3.0 (1.8)	3.1 (2.0)
Younger Drivers	2.0 (2.7)	1.1 (1.1)	1.5 (1.7)

Heterogeneity in the variance meant that the data was transformed prior to analysis using the formula $Y=\sqrt{(X+0.5)}$. There were significant main effect of age [$F(1,22) = 9.790$, $p<.01$] with older drivers rating a higher physical demand than younger drivers. There was also a significant main effect of condition [$F(1.439,31.648) = 6.204$, $p<.05$]. Figure 9.6 displays the data in the form of a line graph showing the differences across age and condition.

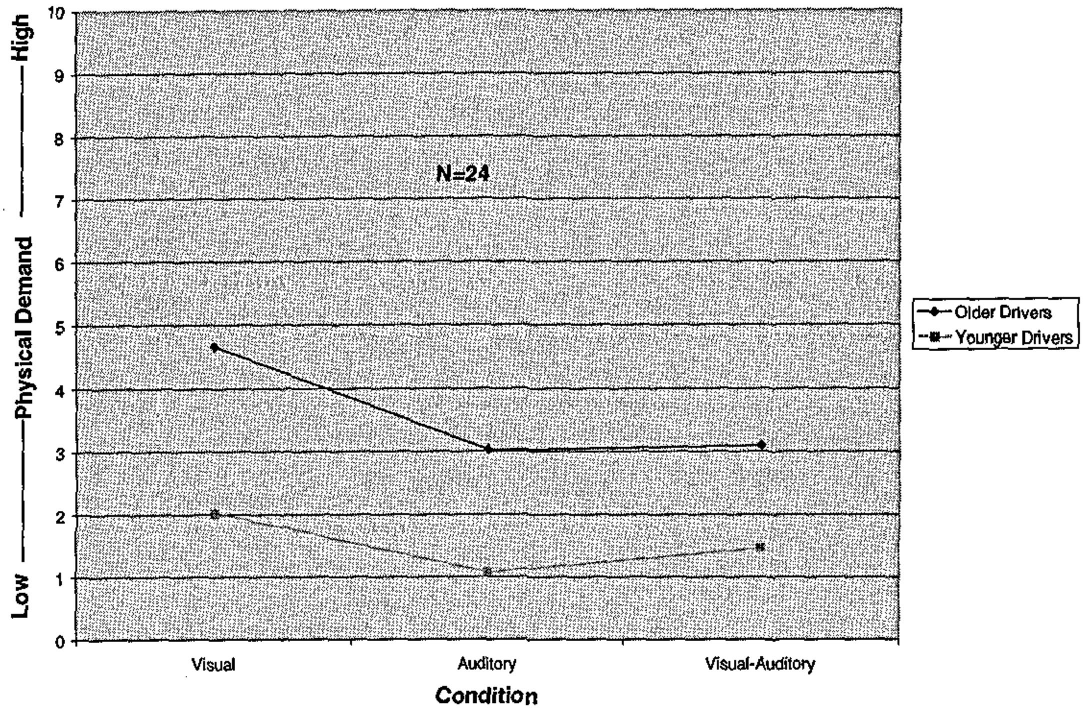


Figure 9.6: Mean Physical Demand subjective ratings across age and condition

Post hoc analysis of the condition means is shown in table 9.12. There was a significant difference between the visual condition and the other two conditions. There was no significant difference between the auditory and visual-auditory conditions.

Table 9.12: Mean Physical Demand Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Physical Demand	3.3 (2.9) A	2.1 (1.8) B	2.3 (2.0) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.4 Time Pressure

This was a measure of how hurried or harassed the participants felt while performing the tasks. Table 9.13 gives the mean subjective ratings for time pressure along with the standard deviations.

Table 9.13: Mean Time Pressure Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	4.6 (2.8)	3.9 (3.0)	3.6 (1.7)
Younger Drivers	3.9 (3.9)	2.9 (2.9)	2.0 (1.5)

There was no significant main effects of age but there was a significant main effect of condition [$F(2,44) = 3.630$, $p<.05$]. The time pressure rating means are displayed in figure 9.7 also.

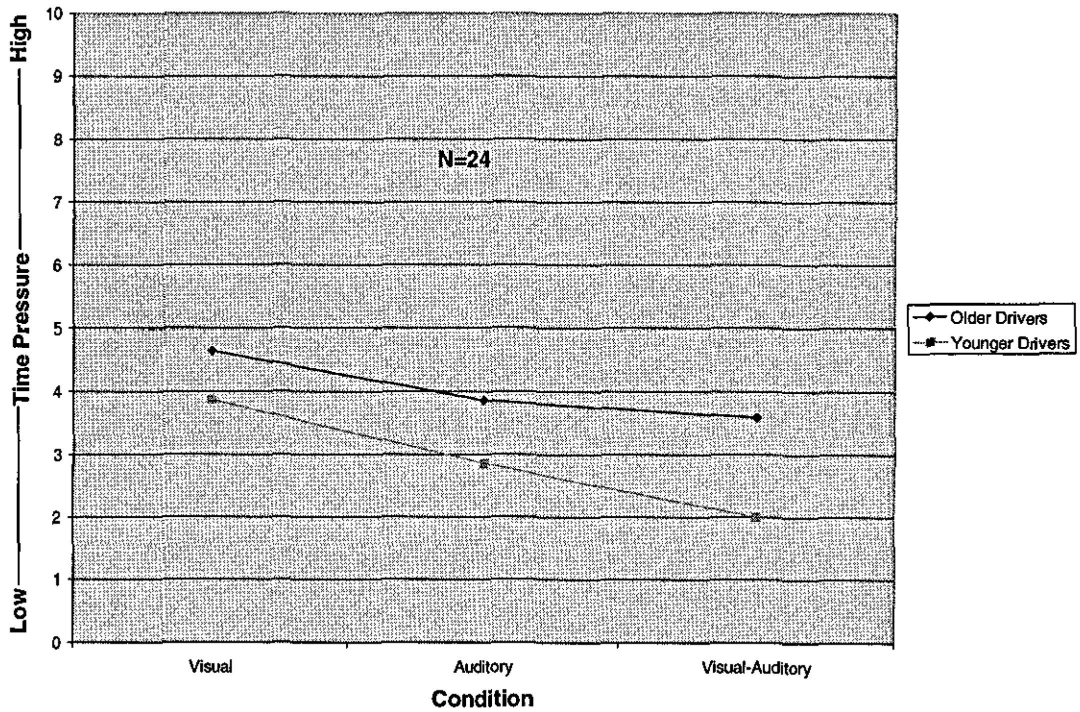


Figure 9.7: Mean Time Pressure subjective ratings across age and condition

Post-hoc analysis of the condition means is shown in table 9.14. There was a significant difference between the visual condition and the visual auditory condition. There was no significance for any of the other comparisons.

Table 9.14: Mean Time Pressure Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Time Pressure	4.3 (3.3) A	3.4 (2.9) AB	2.8 (1.8) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.5 Distraction

This was a measure of perceived distraction from the tasks involved due to auditory or verbal information being displayed. The mean subjective ratings are show in table 9.15 along with standard deviations.

Table 9.15: Mean Distraction Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	5.4 (3.2)	3.4 (2.5)	3.3 (2.6)
Younger Drivers	4.4 (3.0)	2.5 (2.5)	3.1 (2.3)

There was no significant main effect of age but there was a main effect of condition [$F(2,44) = 28.005$, $p<.01$]. Figure 9.8 displays the means for the distraction ratings also, across age and condition.

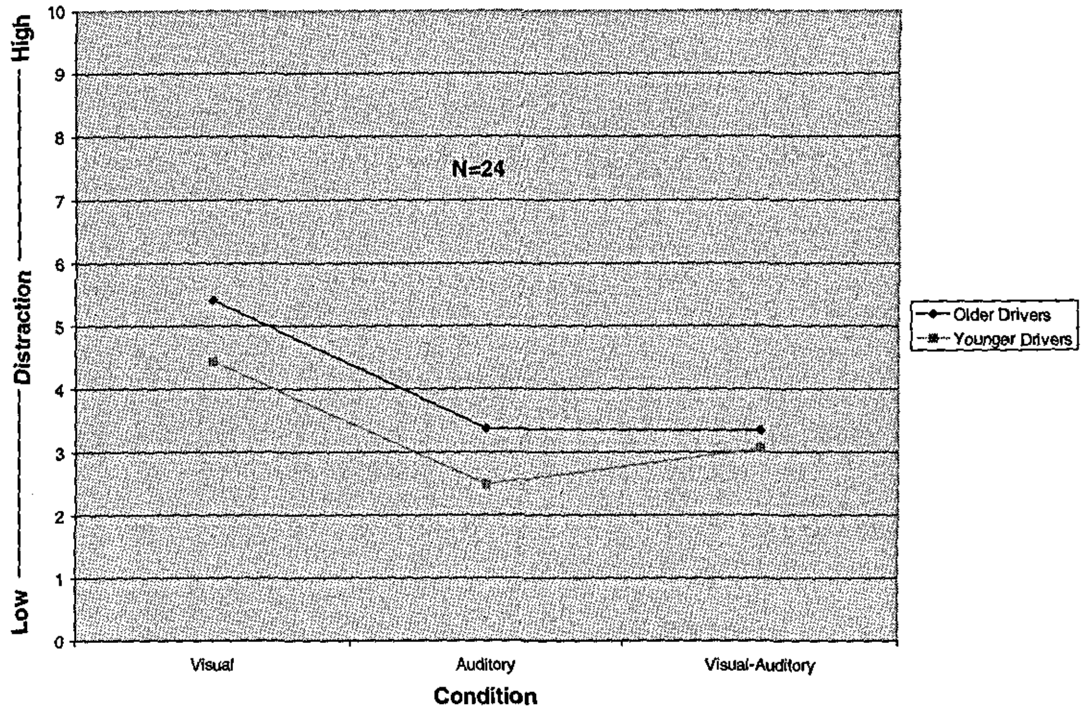


Figure 9.8: Mean Distraction subjective ratings across age and condition

Post hoc analysis of the condition means, are given in table 9.16. The visual condition was rated as significantly more distracting than the other two conditions. There was no significant difference between the auditory and visual auditory conditions.

Table 9.16: Mean Distraction Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Distraction	4.9 (3.1) A	2.9 (2.5) B	3.2 (2.3) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.6 Stress Level

This was a measure of how relaxed or stressed the participant felt while performing the tasks. The means of the subjective ratings across age and condition are shown in table 9.17 along with standard deviations.

Table 9.17: Mean Stress Level Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	5.9 (3.1)	2.8 (1.9)	3.3 (2.2)
Younger Drivers	3.5 (2.6)	1.5 (1.8)	1.1 (1.0)

Due to heterogeneity of variance within the data, a transformation was used (using the formula $Y=\sqrt{X} + \sqrt{(X+1)}$ to equal out the variances) prior to the analysis. There was a main effect of age [$F(1,22) = 7.638$, $p<.05$] with older drivers rating the stress levels higher than younger drivers. There was also a main effect of condition [$F(2,44) = 17.200$, $p<.001$]. Figure 9.9 displays the means for stress level ratings across age and condition.

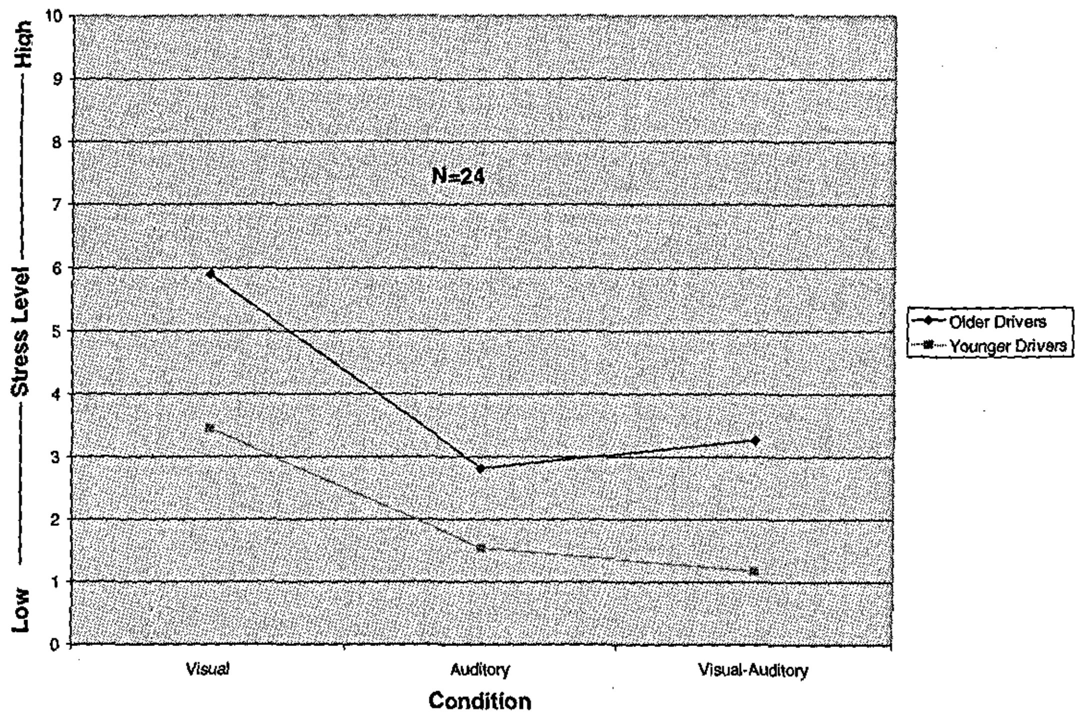


Figure 9.9: Mean Stress Level subjective ratings across age and condition

Post hoc analysis of the means for the conditions is given in table 9.18. The visual condition was significantly different to the other two conditions. There was no significant difference between the auditory condition and the visual-auditory condition.

Table 9.18: Mean Stress Level Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Stress	4.7 (3.1) A	2.2 (1.9) B	2.2 (2.0) B

***Means with the same letter are not significantly different (α=0.05)**

9.3.7 Overall Workload Rating

The perceived overall workload rating was measured by taking a mean across the six measures and then taking a mean of these figures across age and condition. Table 9.19 gives the means for overall workload across age and condition.

Table 9.19: Mean Overall Workload Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	5.8 (2.4)	3.8 (1.8)	3.7 (1.8)
Younger Drivers	4.4 (2.4)	2.8 (1.8)	2.6 (1.4)

There was no significant main effect of age but there was a main effect of condition [$F(2,44) = 18.938$, $p<.001$]. A plot of the means for the overall workload rating is shown in figure 9.10 across age and condition.

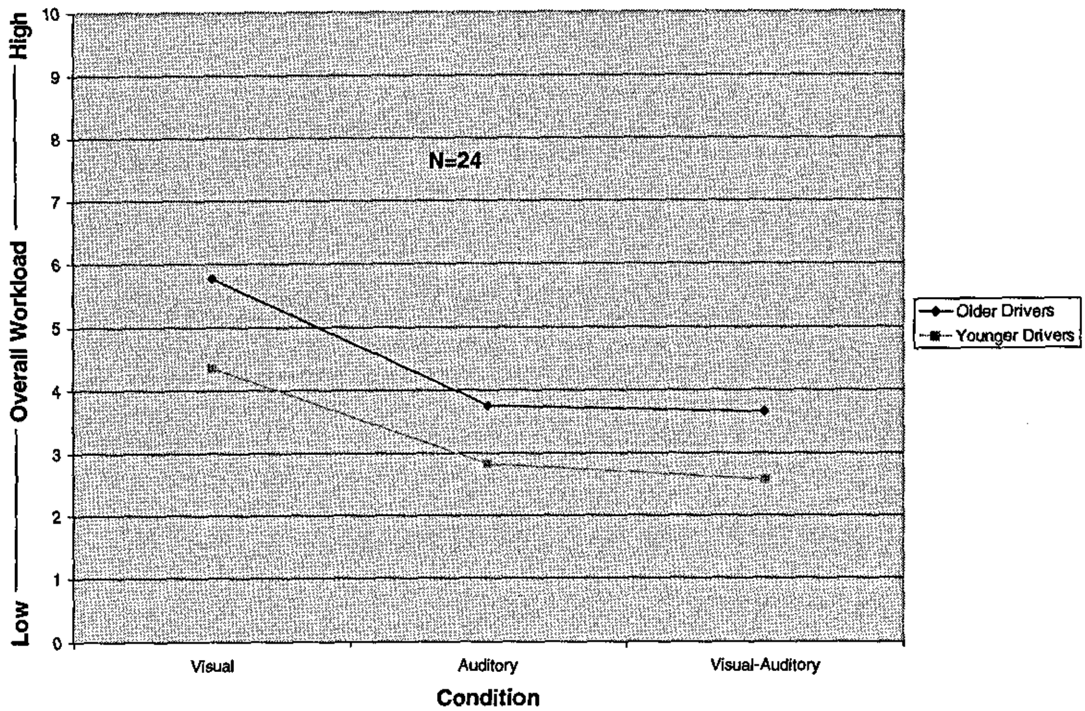


Figure 9.10: Mean Overall Workload subjective rating across age and condition

Post hoc analysis of the condition means is shown in table 9.20. The visual condition had a significantly higher overall workload rating than the other two conditions. There was no significant difference between the auditory condition and the visual-auditory condition.

Table 9.20: Mean Overall Workload Measure for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Overall Workload	5.1 (2.4) A	3.3 (1.9) B	3.1 (1.7) B

***Means with the same letter are not significantly different (α=0.05)**

9.4 System Ratings

This section details the results from the subjective ratings of the system looking at:

- Information Content
- Timing of Information
- Clarity of Information

- Condition Preference

9.4.1 Information Content

This was a measure of the content of the route guidance information provided to the participants. Table 9.21 details the mean ratings across age and condition including standard deviations.

Table 9.21: Mean Information Content Subjective Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	6.8 (3.1)	8.0 (0.9)	8.3 (0.7)
Younger Drivers	6.7 (2.0)	8.4 (1.5)	8.7 (0.9)

There was no main effect of age but there was a main effect of condition [F(1.313,28.889)=7.274, p<.01]. The data from table 9.21 is plotted in figure 9.11 looking at the means across age and condition.

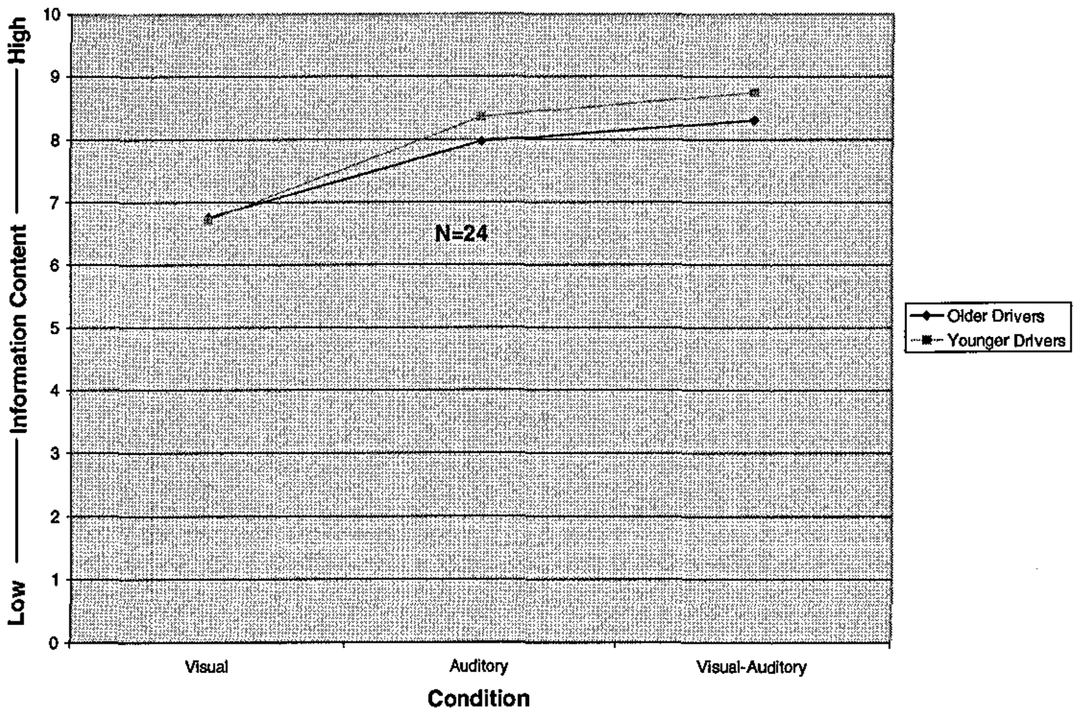


Figure 9.11: Mean Information Content Rating across age and condition

Post hoc analysis conducted on the data is shown in table 9.22. The rating for the information content in the Visual condition is significantly lower than the other two conditions. There was no significant difference between the auditory and the visual-auditory conditions.

Table 9.22: Mean Information Content Rating for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Information Content	5.1 (2.4) A	3.3 (1.9) B	3.1 (1.7) B

***Means with the same letter are not significantly different (α=0.05)**

9.4.2 Timing of Information

Ideally instructions given by a route guidance system should be timely (instructions not given too early or too late). This was a subjective measure of the timing of the information provided by the system. Table 9.23 gives the mean scores across age and condition along with the standard deviations.

Table 9.23: Mean Subjective Timing of Information Rating (standard deviation)

	Visual	Audio	Visual-Audio
Older Drivers	6.3 (2.5)	7.3 (1.7)	8.1 (1.1)
Younger Drivers	6.8 (2.5)	7.2 (1.9)	7.3 (1.9)

There was no main effect of age or condition though for condition there was a strong trend towards a main effect (just missing significance at the 5% level). Figure 9.12 plots the data from table 9.23 across age and condition.

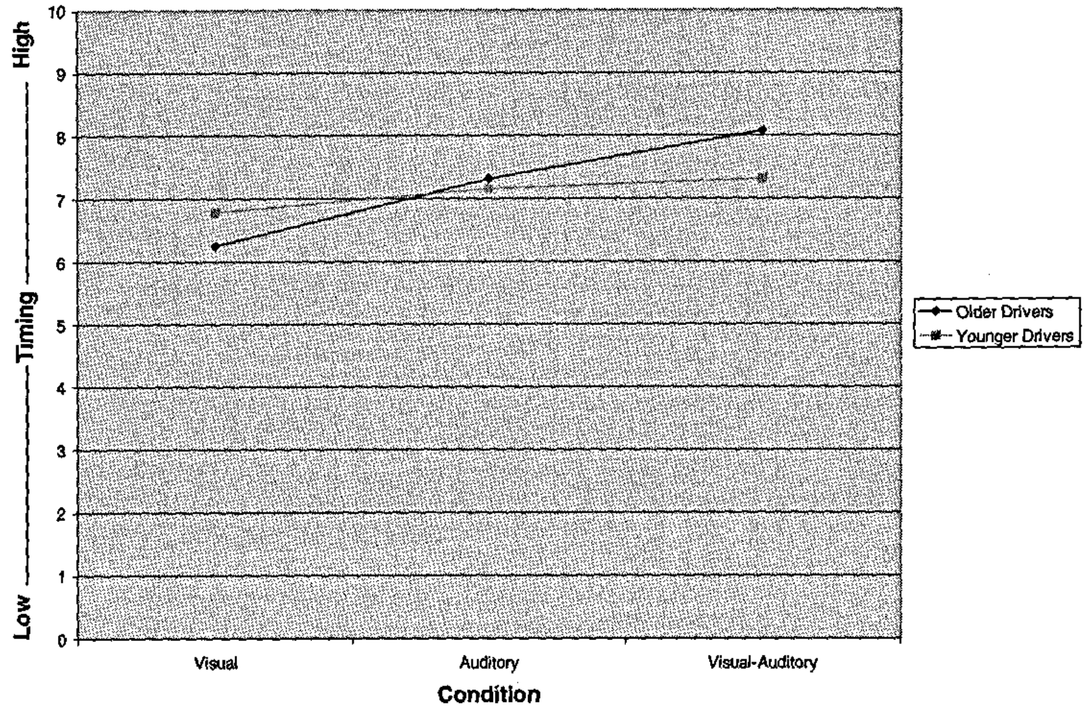


Figure 9.12: Mean Timing of Information Rating across age and condition

As there was a strong trend towards a main effect of condition a post hoc analysis was carried out on the condition means, which are displayed in table 9.24. There was a significant difference between the Visual condition and the Visual-Auditory condition. None of the other comparisons were significant.

Table 9.24: Mean Timing of Information Rating for condition only* (standard deviation)

	Visual	Auditory	Visual Auditory
Car Following Errors	6.5 (2.5) A	7.2 (1.7) AB	7.7 (1.5) B

***Means with the same letter are not significantly different (α=0.05)**

9.4.3 Clarity of Information

It is critical when displaying information that it is visible and audible. Participants were asked to rate the clarity of the information in each of the three conditions. This meant the visual display was rated twice (once on its own and once when the voice was present) and the auditory voice was rated twice (once on its own and once when the visual screen was present.)

Visual Display

The mean subjective ratings across age for the screen display for the two conditions in which it was present, are shown in table 9.25.

Table 9.25: Mean Subjective rating for Visual Display Clarity (standard deviation)

	Visual Screen Only	Visual Screen (when auditory information present)
Older Drivers	6.8 (2.9)	8.1 (1.6)
Younger Drivers	6.9 (2.7)	7.7 (2.1)

There was no main effect of age but there was a main effect of condition [$F(1,22)=4.622$, $p<.05$] with the Visual Screen clarity receiving a higher rating when the audio voice was present. Figure 9.13 plots the means from table 9.25.

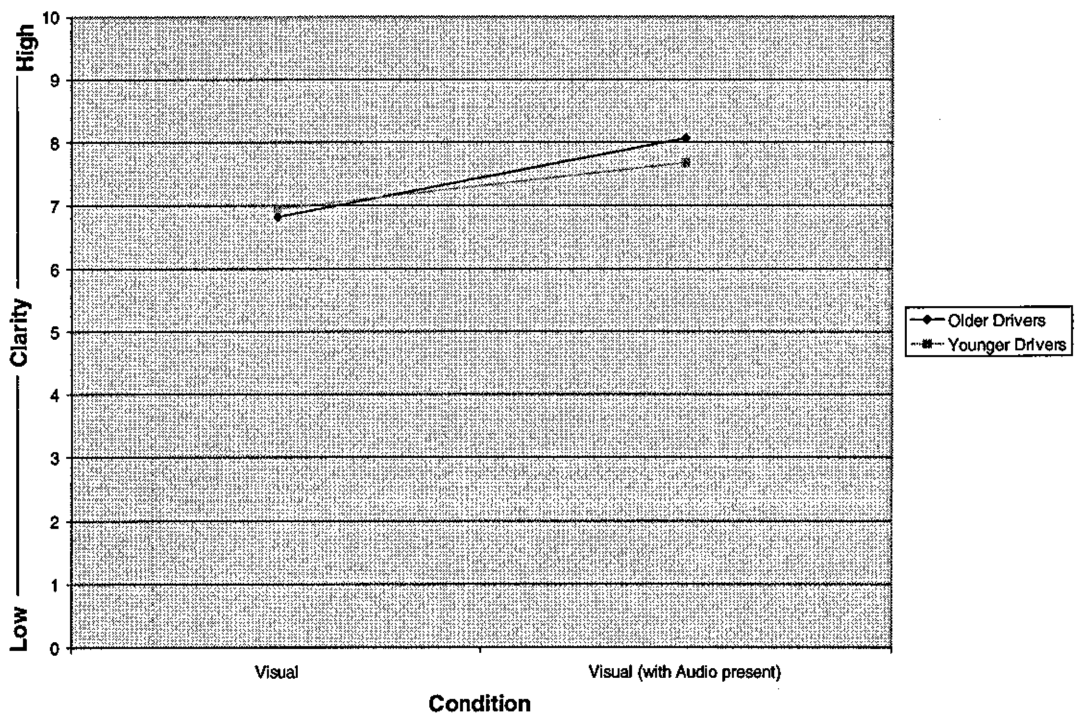


Figure 9.13: Mean subjective rating for Visual Clarity across age and condition

Auditory Display

The mean subjective ratings across age for the auditory display for the two conditions in which it was present are shown in table 9.26.

Table 9.26: Mean Subjective rating for Audio Display Clarity (standard deviation)

	Audio Display Only	Auditory Display (when visual information present)
Older Drivers	7.1 (3.3)	7.4 (3.0)
Younger Drivers	9.2 (1.1)	9.6 (0.4)

There was a main effect of age [F(1,22)=5.676, p<.05] with younger drivers rating the clarity higher than older drivers(this main effect of age was confirmed using conservative estimates on t-tests due to heterogeneity of variance in the ANOVA which were difficult to equal out). There was no main effect of condition. Figure 9.14 plots the data from table 9.26.

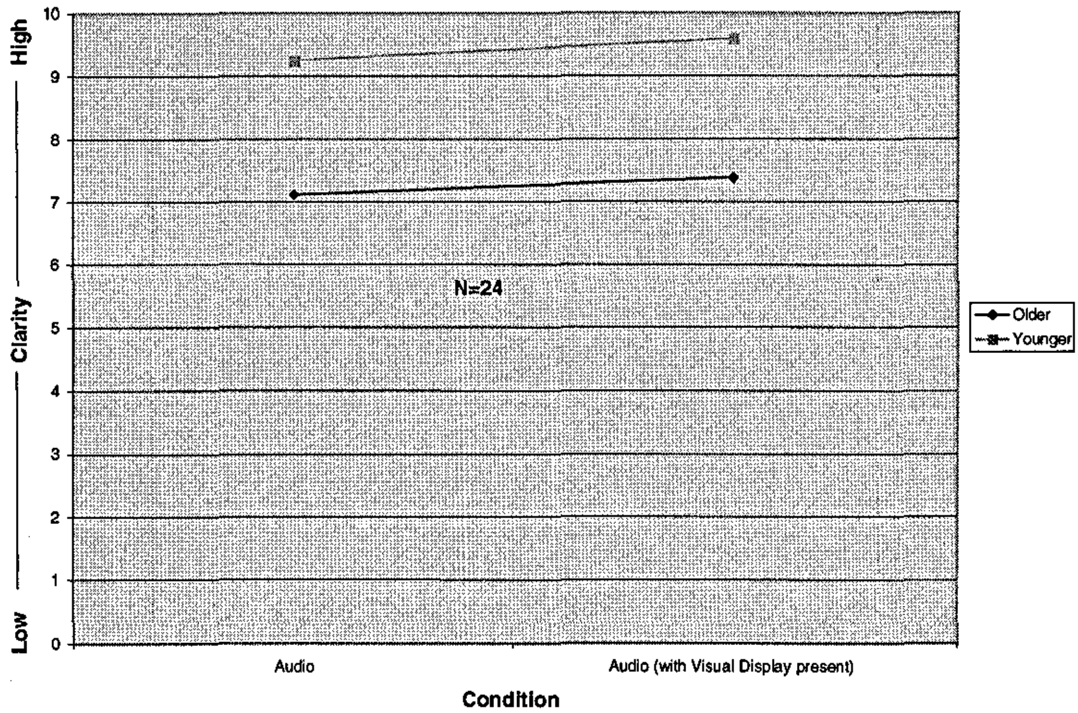


Figure 9.14: Mean Subjective Rating of Audio Clarity across Age and Condition

9.4.4 System Preference

Participants were asked which of the three presentations of navigational information they preferred and which of the three they least preferred. Figure 9.15 shows the system preference for both driver groups.

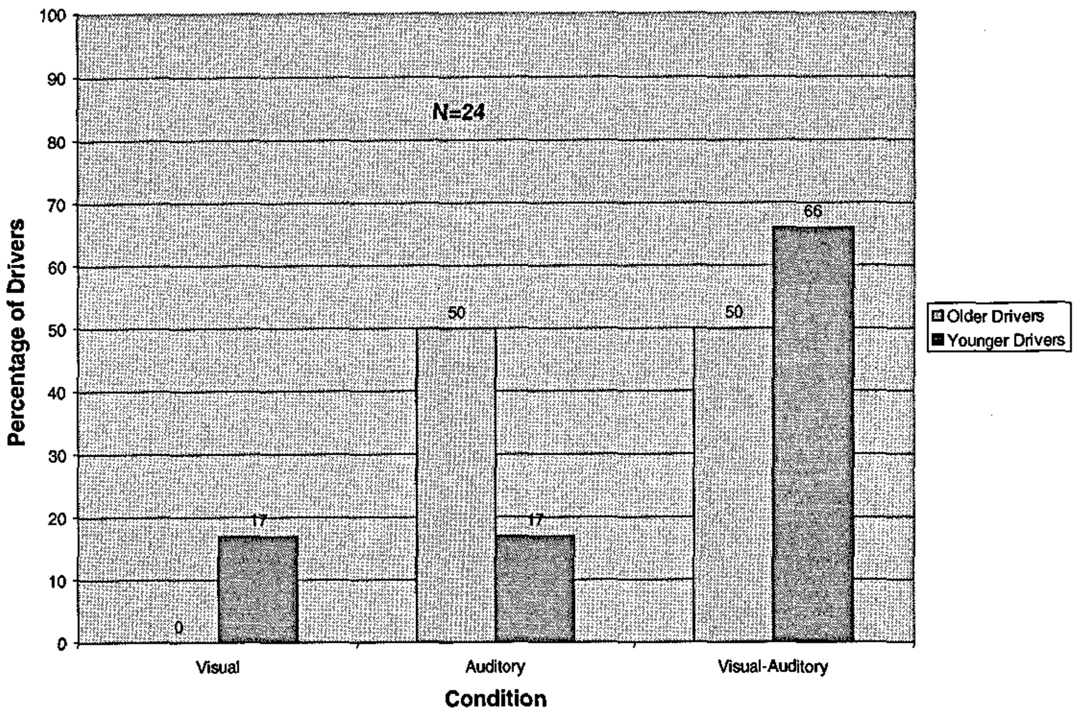


Figure 9.15: System Preference for each driver group

For the older drivers the preference was split equally between the auditory only condition and the visual-auditory condition, with none of this driver group having the visual only as a preference. For younger drivers a majority of the drivers (66%) preferred the visual-auditory system. The remainder of drivers had their preference split equally among the auditory only condition and the visual only condition.

Figure 9.16 displays the percentage of drivers for which the system was chosen as their least preferred. For both driver groups the system most nominated as the least preferred was the visual only condition. None of the older drivers rated the visual-auditory condition as their least preferred.

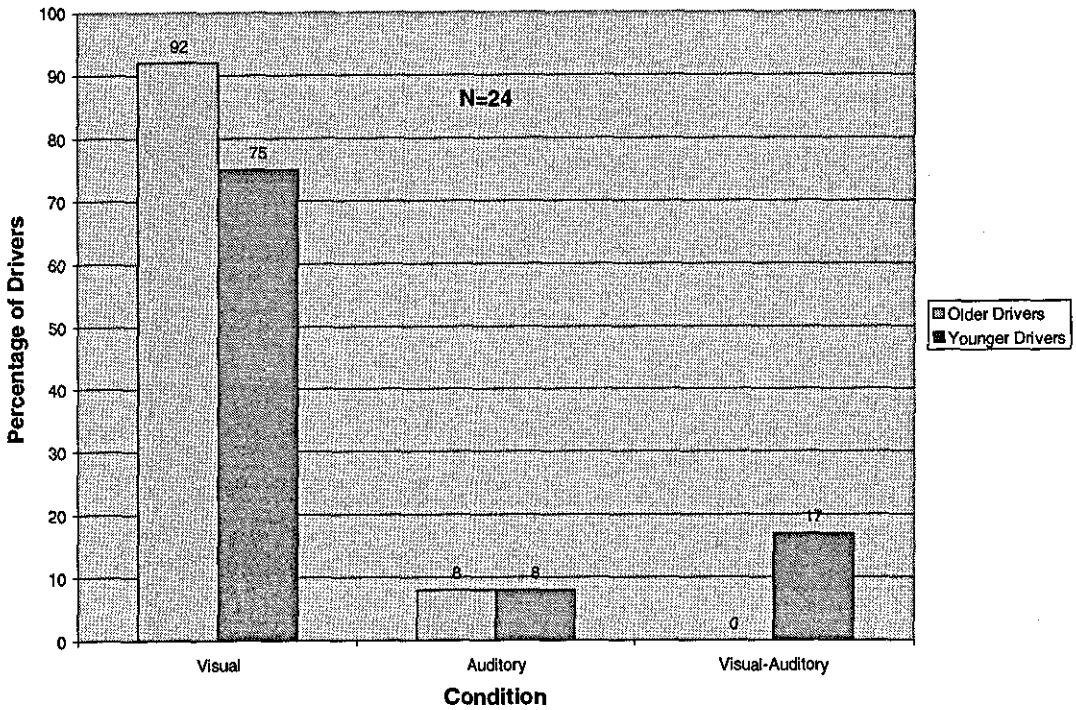


Figure 9.16: System least preferred for each driver group

9.5 Chapter Conclusions

This chapter presented the results for study 2. The aim was to identify the most appropriate way for presenting route guidance information to drivers across ages. There were differences across the conditions with the visual only condition performing worse on both performance and subjective measures, than the auditory only condition and visual auditory. The presence of the visual screen affected older drivers in terms of performance more so than younger drivers. Half of the older drivers showed a preference for the auditory only system and the other half a preference for the visual auditory condition. A majority of the younger drivers preferred the visual-auditory system.

Chapter 10: Study 2 Discussion

10.1 Chapter Summary

This chapter discusses the results from the modality experiment (chapter 9). The first part of the chapter discusses the results of the driver performance measures. The second part of the chapter discusses the subjective results including perceived mental workload, and subjective preferences for modality. The last part of the chapter provides recommendations based on the findings.

10.2 Performance Measures

There were three performance measures: car following errors, missed junction errors, and navigation errors. Each of these was measured across the three conditions and the two age groups.

10.2.1 Car Following Errors

This section discusses the car following errors made by drivers (i.e. how many times the participant failed to respond to the lead car braking within the designated time)

Condition Differences (car following errors)

The visual only display led to the highest number of car following errors from the drivers. The use of visual only displays has been seen to cause distraction from primary driving tasks in previous research (e.g. Lansdown & Burns 1997; Pauzie & Anadon 1993), especially in the frequency and duration of glances towards the display. In the present research, the driver would continually keep glancing at the display. Drivers reported that this was because they had to keep checking to see if the screen had changed, so as not to pick up instructions too late. The consequences of such behaviour was the participants more frequently missed the lead car braking. This obviously causes concern for real world driving as such behaviour could easily lead to an accident. The consequences of this have already been realised in Japan where accidents have been attributed to visual displays of route-guidance systems (see chapter 3).

When a visual only display is present this is the only means for the driver to obtain the information so it is not surprising this caused the highest amount of car following errors. Combining auditory information with the visual display significantly reduced the number of car following errors. The driver no longer had to totally rely on the visual display for information. Indeed a number of drivers reported not using the screen at all as it was too much of a distraction. Superiority of combination displays over visual only displays in terms of distraction, has also been found by other researchers (e.g. Burns & Lansdown 1997; Burenett & Parkes 1993)

The use of auditory information only, saw a further significant reduction in the amount of car following errors for all drivers. Here the driver was totally reliant on the verbal information being given, and there was no longer any visual screen to look at. This meant the driver could fully attend to the primary task of car following. The voice appeared to cause very little distraction to this task. This finding substantiates that it was the visual screen causing the distraction and car following errors.

Age Differences (car following errors)

There was a significant difference between older and younger drivers in the amount of car following errors made. Older drivers performed worse than younger drivers. Importantly there was a significant interaction between age and condition. Looking at simple effects revealed that there were significant differences between the two driver age groups in the visual only condition and the combination condition, but there was no significant difference in the auditory only condition. This suggests that the visual screen was responsible for older drivers' poorer performance as this caused more distraction than for younger drivers. The visual display appeared to expose declines in ability mores so than the auditory display. This is because to obtain navigational information the driver would need to look away from the main screen in order to see, perceive process, and make a decision based on the information presented. With age each of these processes is slower, meaning the driver would have their eyes 'off the road' for a longer period of time. Previous research has also shown that older drivers look at navigation displays for longer periods of time than younger drivers (e.g. Wierwelle et al 1988; Pauzie & Anadon 1993). With auditory information any slower processing times would not so much effect the car following exercise as the driver could focus on this at all times.

10.2.2 Missed Junction Errors

Missed junction errors measured how many times the driver failed to make a decision for a particular junction.

Condition Differences (missed junction errors)

The visual screen only condition caused more missed junction errors than the other two conditions. However this was only significantly different to the auditory only condition. Burns & Lansdown (1997) also found that drivers missed more junctions in the visual only condition. The reasons for the high error rate appeared to be due to the lack of temporal information, which is present in auditory displays e.g. "Turn now". Drivers on receiving the visual information would have to try to match it with what was happening on the main screen. As a junction was approaching drivers would frequently look at the screen to see if the junction matched in order to make a decision if that was the junction the route guidance information was for. Often in doing this the driver would not be able to decide in time and so would not be able to give a letter choice for the direction they intended to go. Also on looking at the route guidance screen they sometimes missed the junction altogether.

Adding auditory information to the visual screen appeared to reduce the amount of such errors but not significantly so. However removing the visual screen altogether did solve this problem. The temporal aspects of the auditory information were a very powerful cue as to when to turn and which way. Removing the visual information also removed any conflict between the information presented on the screen and that presented by speech. Also having the screen removed meant the auditory information would receive their full attention, and the driver also didn't have to look away from the main screen, meaning there was also less chance they would miss the junction altogether.

Age Differences (missed junction errors)

There was a significant difference between older and younger drivers in the number of missed junction errors. Older drivers made more errors than younger drivers across all three of the conditions. The car following task and navigational task were both run at a set speed and required quick decision making. As was noted earlier drivers were distracted more by the visual screen, and previous research has shown longer glance times (e.g. Wierwelle et al 1988). In simply taking longer time to look at a visual screen, they had more chance of missing the letters which appeared at each junction, and thus couldn't give a decision. However this only explains some of the errors as older drivers also had a significantly higher error rate when the screen wasn't present (i.e. the auditory only condition). This suggests that declines in decision making abilities were exposed by this task leading to more indecision at junctions by the older drivers.

10.2.3 Navigational Errors

This was a measure of how many navigation errors were made by the drivers (i.e. they picked a letter to indicate direction but it was the wrong decision).

Condition Differences (navigational errors)

The visual condition caused significantly more navigational errors than the other two conditions. Previous research has also found high navigation error rates attributable to a visual only display (e.g. Burns & Lansdown 1997; Verway & Janssen 1988) Again this appeared to be due to the lack of the temporal aspects afforded by the auditory display. Drivers in attempting to match up what was on the display to what was on the screen sometimes gave the direction shown on the screen at the wrong point in time. Again introducing auditory information appeared to resolve this problem. In both the combination and auditory alone, the information given by the voice instructions reduced errors to almost zero. One of the problems identified was that when visual information first appeared to alert the driver of an approaching junction, this information contained the road layout and the direction to turn. When auditory information was present auditory the instruction "Junction Approaching" was given with the direction provided when the driver got closer to the junction. Thus if a side road appeared after the time the visual instruction had been given, and no auditory information was present, drivers often mistook it for the turn. It suggests that in the visual only condition, drivers did not manage to pick up the road layout information but did pick up the direction of the manoeuvre, and so took the next turn that occurred, even though the road layouts didn't match. Adding auditory instructions to the visual instructions negated this, as it seemed to be the dominant of the two instructions. In this situation, even though the visual instruction was indicating a turn, they would wait for the auditory instruction before making any manoeuvre from their current path.

The auditory instructions alone also made for very few errors. Indications for side roads were always accompanied by distance information (e.g. "In 100 yards turn left"). For junctions drivers were first alerted to the junction approaching (e.g. roundabout approaching"), and then as they got closer they would receive the direction as well (e.g. "at the roundabout turn left"). The first junction alert allowed the driver to know it was a junction to turn at, and so drivers would ignore any side roads, and waited for the junction and further instructions of which way to turn. Even though the junction information was shown on the visual screen, without a voice instruction to alert the driver to this the information was not picked up.

Age Differences (navigational errors)

There was also a significant difference in age for the amount of navigational errors made. Older drivers made more navigational errors than younger drivers. This is consistent with previous research by (e.g Walker et al 1991). However there was an interaction between age and condition. Examining simple effects revealed no differences between the older and younger drivers in the auditory alone condition, and the combination condition. However there was a significant difference between the older and younger drivers in the visual condition, with older drivers making significantly more errors than younger drivers. Here the younger drivers again made virtually no errors. It seems that in the visual only condition younger drivers did manage to pick up on the road layout information and so made less errors. In fact there was no real difference between any of the conditions for younger drivers. It was the older drivers that had the main problem picking up road layout information in the visual only condition. Considering that the dominant part of symbol in the visual condition was the arrow, and declines in perception and processing abilities as we age, meant that it was this information that was picked up and acted upon. Again the addition of auditory instructions resolved the situation for older drivers.

10.3 Perceived Workload Measures

The perceived workload measures were taken across six factors: Mental demand, Mental Effort, Physical Demand, Time Pressure, Distraction and Stress Level. Each of these will be discussed separately, before discussing the overall workload which is an aggregate of the six factors.

10.3.1 Perceived Mental Demand

This was a measure of the perceived mental demand placed on the driver by the tasks performed.

Condition Differences (mental demand)

The mental demand placed on the driver was highest for the visual only condition. The drivers here had to take all of the information from the screen while simultaneously performing the car following task. Having no auditory information meant the driver had to decide when to look at the screen to obtain information, which would have added to the extra demand. This would often result in the driver making frequent glances to see if the information had changed. When voice instructions were included this reduced the mental demand, as the driver was fed information at the route guidance systems choosing and so reduced some of the demand placed on the driver. There was no difference between the auditory only and the combination display which helps substantiate this reasoning.

Age Differences (mental demand)

The older drivers in each of the conditions rated the mental demand higher than the younger drivers though this was not found to be significant.

10.3.2 Mental Effort

This was a measure of the perceived mental effort required by the driver, in order to perform the tasks.

Condition Differences (mental effort)

The mental effort required by the driver was highest for the visual only condition. Again drivers would have to take all of the information from the screen. As only short infrequent glances at the screen would allow for good performance on the primary task, the information displayed had to be perceived, processed and acted upon very quickly. It was important here for drivers to pick up on road layout information, to be able to match the junction at which they needed to turn. Performing all of these tasks at once required a lot of mental effort. As with mental demand the voice instructions helped reduce the mental effort required. There was no significant difference between the auditory only condition and the combination condition. The auditory information again afforded temporal information, and so it wasn't so critical to pick up road layout information from the screen to identify the point at where to turn.

Age Differences (mental effort)

As with mental demand older driver rated mental effort as higher than younger drivers though again this wasn't significant.

10.3.3 Physical Demand

This was a measure of the perceived physical activity endured by participants when performing the tasks.

Condition Differences (physical demand)

The perceived physical demand required in performing the tasks was highest for the visual only condition. In this condition the driver would have to look at the screen to obtain the navigational information. This meant more physical movement of the head and more eye movement. Also the frequent looking at the screen observed in this condition would have added to the physical demand. In doing this drivers would have continually have to keep focussing and re-focussing as they looked between the two screens. Again, as with the two previous workload measures covered, the introduction of the auditory information helped reduce demand on the driver. There was no difference between the auditory only and the combination conditions. For these conditions it was not as necessary to look at the screen and therefore the physical demand was reduced.

Age Differences (physical demand)

Interestingly there was a significant difference between older and younger drivers for perceived physical demand. Even though the tasks were not as physically demanding as driving a car, differences were still apparent. Having to look at the screen possibly effected older drivers more due to neck rotation problems. Also constantly having to focus and refocus was possibly more demanding due to declines in ability to accommodate the eye (see chapter 2). When the auditory information was present the physical demand lessened but was still higher than younger drivers. It is possible that actually carrying out any of the tasks in the lab was more physically tiring for older participants than younger participants.

10.3.4 Time Pressure

This was a measure of how hurried or harassed the participants felt while performing the tasks.

Condition Differences (time pressure)

The perceived time pressure was highest for the visual only condition. In this condition drivers had to continually glance at the screen to acquire prior warning of upcoming events. As they had no control over their speed this added to the time pressure, made all the more difficult by having to constantly having to monitor the route guidance screen for information, and then having to match the information to that on the main screen. The auditory information when presented alone did not significantly reduce the time pressure felt by drivers. In this condition the drivers again had only one information source and so would have to make sure they heard, perceived, and understood the information presented to them, at times dictated by the route guidance system. Again because the driver could not control the speed of the car this added time pressure. The combination of auditory and visual information did help relieve time pressure significantly more so than the visual only condition. This appears to be because the driver now had choices of when to take on information, and also two options to obtain the information. When the auditory system gave information this not only provided instruction but also warned the driver of an upcoming event. This meant the driver would also be able to confirm information or obtain information from the screen if they required. This produced less time pressure.

Age Differences (time pressure)

The older drivers rated the perceived time pressure in each condition higher than younger drivers though this wasn't significant.

10.3.5 Distraction

This was a measure of the perceived distraction from the primary task due to information presented by the route guidance system.

Condition Differences (distraction)

The perceived distraction from the route guidance system was highest for the visual only condition. This is not surprising as the driver would have to look away from the main screen in order to pick up route guidance information. Also as stated before the drivers had to frequently keep glancing at the screen to see when it had changed. Adding auditory instructions to the visual information significantly reduced the perceived distraction. No longer having to rely totally on the screen information meant that driver didn't have to look away from the main screen so often. Having no screen at all (i.e. the auditory only condition), was not significantly different to the auditory-visual combination. This suggests that the perceived distraction from the screen was not a problem if the voice instructions were present.

Age Differences (distraction)

The older drivers rated the perceived distraction in each condition higher than younger drivers though this wasn't significant. However it should be noted that a number of the older drivers reported not using the screen in the visual-auditory combination condition as they found it too distracting.

10.3.6 Stress Level

This was a measure of how relaxed or stressed the participant felt while performing the tasks.

Condition Differences (stress level)

The perceived stress level was highest for the visual only condition. Again having to keep looking at the screen to pick up information, or to see if the information had changed and match it to information on the main screen, appeared to be more stressful than the other conditions. The time pressure also added to this stress. The addition of auditory information to the visual screen helped reduced stress. Taking away the screen altogether did not reduce stress any further.

Age Differences (stress level)

There was a significant difference between age groups for the perceived stress level. Older drivers found performing the tasks more stressful, possibly because of the nature of the tasks (e.g. forced time pressure, quick decision making) it was more difficult for them due to declining abilities. Also it appeared that older drivers were more concerned with performing well than younger drivers. During the trials older drivers after seeing the tasks appeared concerned they wouldn't do very well. An added stress to this was the fact many of the older drivers hadn't often used computers.

10.3.7 Overall Workload

The perceived overall workload was calculated by taking a mean of the six workload factors described above.

Condition (overall workload)

The visual only condition produced the highest overall perceived workload. This is consistent with previous research by Burns & Lansdown (1997). This is not surprising as it caused the most workload over each of the factors. This suggests that from the drivers point of view the visual screen alone is not conducive to supporting the navigation task. However when in combination with visual information there was a significant reduction in overall workload. The auditory alone produced no further reduction in perceived workload. So in terms of workload the use of auditory or a combination of auditory-visual modalities appears to be the best options. An advantage of the combined modality is it also allows the driver to pick up information when they choose, and also it can provide information which would be difficult to obtain from auditory instructions e.g. junction layout information.

Age Differences (overall workload)

There was no significant difference between older and younger drivers in terms of the overall workload. This was surprising as for every factor in nearly every condition older drivers gave a higher rating. However many of these were not significant.

10.4 Subjective Ratings

The participants were asked to rate the route guidance information in each of the three conditions across three criteria: content of the information, timing of the information, and clarity of the information.

10.4.1 Information Content

Participants were asked to rate the content of the information presented to them across the three conditions.

Condition Differences (information content)

The information content was rated favourably by drivers. However the rating of the visual information content alone was significantly lower. Comments were made by drivers that visual information alone was satisfactory but when combined with the auditory information it was excellent. The auditory information was seen to be very good on its own, as well as in combination with the visual information. It appeared that the visual information was okay, but did require auditory information to make it clear. It is suggested that this was more to do with the auditory information alerting the driver to the screen information. Thus the driver would have time acquire the information as intended by the system. With no auditory information the driver may have missed or seen very late what was on the screen, therefore some of the information may not have been picked up.

Age Differences (information content)

There was no significant difference between older and younger drivers in the rating of the information content.

10.4.2 Timing of Information

Participants were asked to rate the timing at which route guidance instructions were given for each of the three conditions.

Condition Differences (timing)

The ratings across all three of the conditions were favourable. However in the visual only condition the rating was significantly lower than the other two conditions. The difficulty here was that participants sometimes didn't see the visual system display change and so when they did pick up on the information it was sometimes quite late. Adding auditory instructions to the visual display increased the rating. The auditory information would alert the driver to a screen change on the visual display and so the timings were rated more favourably. The auditory only condition didn't fair significantly better than the visual only condition or significantly worse than the combination condition. It suggests that the combination condition was rated the highest due to the flexibility it provides.

Age Differences (timing)

There were no age differences in the rating of the timings, across the three conditions. The system was set with timings taken from the recommendations in chapter 6 and appears to have been suitable for older drivers as well as younger drivers.

10.4.3 Clarity

Participants were asked to rate the clarity of the information presented to them for each of the three conditions.

Condition Differences (clarity)

The visual display was rated favourably by drivers. This rating significantly increased when auditory information was also present. Drivers commented that with the addition of auditory information the visual information became much clearer. Even though the visual screen was the same for each condition the addition of auditory information gave it more meaning. The auditory information alerted the driver to a change in the screen information and so they would have time to look, and acquire information they had just received as a spoken instruction. The clarity rating of the visual screen therefore was dependent on the auditory information being available. The auditory information was also rated favourably. This rating was the same whether alone or combined with the visual screen. The clarity of the auditory information was therefore not dependent on the screen.

Age Differences (clarity)

Auditory clarity was rated significantly higher by younger drivers than older drivers. Some of the older drivers complained the voice was sometimes not clear and sounded slightly muffled. This was more to do with hardware, as the voice was recorded into a computer, and although it was clear it could have been clearer. It is worth noting however that none of the younger participants mentioned this. Declines in hearing of the older drivers may have made it more noticeable. This must be a consideration in the design of systems as in the vehicle environment there is also much background noise.

10.4.4 Modality Preferences

The most preferred method of information presentation was the visual-auditory combination, and the auditory alone. More of the older drivers had a preference for the auditory alone than younger drivers. Older drivers through performance and subjective measures indicated a greater distraction by the visual screen. Indeed as mentioned earlier, some older drivers reported not using the visual screen in the visual-auditory condition due to the distraction caused. The least preferred method of information presentation for nearly all drivers was the visual only display. Comments for this choice mainly referred to the distraction caused by the system.

10.5 Recommendations for Modality

The performance measures and mental workload provide evidence of the superiority of the auditory and combined visual-auditory display over the visual only display. The superiority of combined displays over visual only displays has been demonstrated in previous research (e.g. Burns & Lansdown 1997; Burnett and Parkes 1993). There were very few differences between the auditory and visual-auditory combination. However the auditory alone display achieved the lowest car following error rate. This is not surprising as the driver did not have to look away from the main screen at any time. However it does indicate the potential distraction that can be caused by visual screens.

Concerning age there was evidence that the visual screen caused more distraction for older drivers than younger drivers (e.g. more car following errors than younger drivers when the visual screen was present). Half of the older drivers also showed a preference for the auditory only display. Considering this it appears that for older drivers that an auditory only system may be preferable. However it has been argued that it is not possible to use verbal messages only, due to the complex nature of some junctions (e.g. a roundabout with more than 4 exits) in the environment (Alm et al 1992). This is due to the difficulties in describing such junction layouts, a task to which the visual screen is most suited. Indecision at complex junctions through lack of information in itself can cause distraction and affect safety. However Alm et al (1992) and Lansdown and Burns and (1997) recommend that the verbal information should be the primary source of information, with visual information as redundant support. The results of the present study strongly support this recommendation, especially with respect to older drivers.

10.6 Chapter Conclusions

This chapter considered the most appropriate modality for the display of route guidance information. Both the auditory only display and the combined auditory-visual display were superior to the visual only display. This was based on evidence from performance data, mental workload, and subjective measures. There were few differences between the auditory only display and combined visual-auditory display. There was evidence that the visual display when present distracted older drivers more than younger drivers. This was based on performance measures and subjective preferences. However due to the advantages of the visual display in providing junction layout information it is suggested that this modality should not be discounted altogether. In light of the findings it is recommended that a combination display be used but the primary source of information should be provided through the auditory channel. This is imperative for older drivers in order to minimise any distraction caused by the visual screen.

The content and timing of instructions provided by the route guidance system were also rated. These were based on recommendations made in chapter 6. Both the content and timing were rated favourably by younger and older drivers for the auditory alone display and combined auditory-visual display. This provides an initial validation of the recommendations made in chapter 6. The presentation of information for the visual information and verbal information was also rated. Again the rating was favourable and again provides an initial validation of the presentation method of the information.

Chapter 11: Thesis Recommendations & Route Guidance System Evaluation

11.1 Chapter Summary

This chapter brings together the recommendations from the two previous studies, to produce a set of recommendations for the content, timing and presentation of route guidance information. The first part of the chapter presents these recommendations. The second part of the chapter evaluates a commercially available route guidance system against these recommendations, identifying their current status in meeting the needs of the older driver.

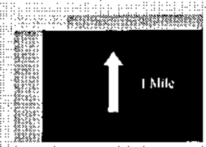
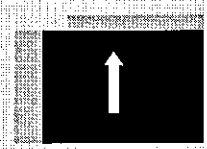
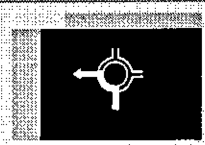
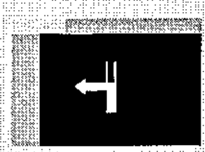
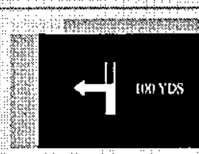
11.2 Introduction

The previous chapters have reviewed literature and described and discussed two studies. Study 1 produced a driver model for the navigation and a set of recommendations for the timing and content of information to be provided by a route guidance system with respect to older drivers. The second study incorporated these recommendations into a system, to try and identify the best modality for their presentation, again with respect to older drivers. Thus far the thesis has satisfied the first three objectives set out in the research aims in chapter 1. This chapter aims to satisfy the last two by bringing together the two sets of recommendations from the previous studies and to evaluate a current market available route guidance system against the recommendations.

11.3 Thesis Recommendations

Chapter 6 set out recommendations for the content and timing of information, taking into account the needs of the older driver. Chapter 10 dealt with modality issues again taking into account the needs of the older driver. Table 11.1 below provides the set of recommendations for the content and timing of information and how instructions should be displayed.

Table 11.1: Recommendations for Route Guidance Information

Stage	*Timing*	*Information Content*	*When to use*	*Example Verbal Instruction*	*Example Visual Instruction*
Assessment (Information only provided if junctions are more than 25 seconds apart)	0-5 seconds after leaving junction.	Absolute distance in reference to current path	Driver has turned onto a new path. The next manoeuvre is greater than 60 seconds away	"Follow road for 1 mile"	
		Cost-based distance in reference to current path	Always except when above rules apply.	"Keep going straight on"	
Prepare (Information only provided if junctions are more than 20 seconds apart)	20 seconds prior to junction.	Node type in reference to next junction	The driver is approaching a junction.	"Roundabout/ Junction approaching"	
		Prior path information in reference to	The driver is approaching a side road.	"Left turn approaching"	
Execute (Information only provided if junctions are greater than 5 seconds apart)	10 seconds prior to junction	Ego-centred direction combined with node reference for the next junction	When approaching junctions with 3 exits (angled so left/straight on/and right tags naturally apply.)	"At the roundabout/junct ion turn left"	
		Ego centred direction combined with absolute distance information.	When approaching a side road.	"In 100 yds turn left"	

These recommendations are based on a combined modality of visual and auditory information being displayed, recommended in chapter 10. The auditory information forms the primary information to be supplied to the driver also recommended in chapter 10. The visual information displayed on the main area of the screen should therefore never change without a verbal instruction.

The instructions are provided mainly at the micro level (i.e. junction to junction) as explained in chapter 6. The only exception to this is the absolute distance provided at the assessment stage. This is information at the meso level (see chapter 6).

These recommendations set out the basic requirements that a route guidance system should satisfy and therefore are not exhaustive. Further research is required on how to deal with complex junctions (highlighted in chapter 6), and how to incorporate information at the macro level (e.g. distance to destination, location of destination), as this was shown to be useful for drivers. Concerning information at the macro level, it is suggested that such information should be displayed on the screen at all times. This would allow the driver to acquire the required information when they have spare time and their mental workload is low.

Even though the recommendations were aimed at older drivers, there were many similarities in their needs when compared to younger drivers. These recommendations therefore should be suitable for both driver age groups. However there was evidence that younger drivers would also like more advance information on manoeuvres (i.e. information at the meso level). It is possible that an optimum solution would be to allow the system to display different levels of information. This again requires further research.

11.4 Route Guidance System Evaluation

During the time taken to conduct this research route guidance systems have rapidly changed and have also become more readily available. An evaluation of a current commercially available system was required to put the recommendations in context. The aim was to illustrate the use of the recommendations by identifying weaknesses and strengths of a route guidance system, in meeting the needs of the user (in this case older drivers). This was accomplished by analysing the content, timing, and presentation of route guidance information employed by the chosen route guidance system.

11.4.1 Method

Apparatus

The evaluation was conducted using a Land Rover Discovery fitted with a popular route guidance system. The route guidance system was fixed to the top of the dashboard in a central position. A video camera was used to record all events.

Routes

The routes chosen were the same as the field trial (see chapter 4) and so the data collected would be based on instructions given by the route guidance system in the same environment.

Procedure

The vehicle was driven to the starting destination of Route 1 used in the field trial. The destination required was entered into the system. A driver then drove the vehicle following the route guidance instructions while the experimenter sat in the back and recorded events happening on the road and information provided by the route guidance system, using the hand held video camera. Once the first destination was reached, the second destination was entered and the procedure repeated covering route 2, the same as that used in the field trial.

11.4.2 Data Analysis

The audio and visual tracks of the video recordings were transcribed taking into account all occurrences. Every event that occurred was noted along with the time it happened (the start of the journey being 0). Table 11.2 below gives a breakdown of the events, which were transcribed.

Table 11.2: List of events recorded in the driving task

Event	*Explanation*
Verbal commands.	The voice instructions provided by the route guidance system.
Visual Commands	The visual information provided by the route guidance system (including a diagram)
Junction Reached/Junction Exited	The time was taken when driver reached/ exited a junction - the junction was given a number depending on its order along the route
Slow Moving/began driving normal speed	If the car was slowed by traffic the time was taken when this happened. The time was also noted when the car resumed normal speed.
Stopped in traffic/Began driving	When the car was stopped in traffic the time was noted. Once the car began moving the time was noted again.
Destination Reached	The time upon arrival noted.

The transcriptions were entered into Microsoft EXCEL, giving a spreadsheet of all the events recorded on both of the routes travelled. Table 11.3 presents an example of one of the transcription spreadsheets. The left hand column lists the event, the middle column gives the time elapsed since the journey began, and the third column gives any dialogue in the form of a question or commentary they made. The third column also lists any additional notes, where there may be doubt of the context of the question.

Table 11.3: Excerpt from video transcription (time elapsed in minutes and seconds)

Event	Time (secs)	Dialogue/Comments
Display Information	*149*	Roundabout with white direction arrow.
Voice Information	*152*	"At the roundabout take the first exit."
Junction 2 Reached	*167*	
Junction 2 Exited	*173*	
Visual Information	*173*	Clear straight on arrow with white smaller turn right arrow above.
Visual Information	*222*	White Arrow on crossroads indicating right turn .
Voice Information	*225*	"In 100 yds turn right."
Junction 3 Reached	*234*	
Junction 3 Exited	*241*	
Visual Information	*243*	Roundabout with white direction arrow.
Voice Information	*245*	"At the roundabout take the first exit."
Junction 4 Reached	*259*	
Junction 4 Exited	*264*	
Visual Information	*264*	Clear straight on arrow with white smaller arrow above with roundabout pointing left.
Stopped In traffic	*267*	
Moving slowly in traffic	*301*	
Stopped in traffic	*333*	

This allowed examination of the way the system worked in terms of how information was displayed and when it was displayed during driving.

11.4.3 Results and Discussion

The results give an insight into the way the system used and displayed information and the timing of the information. An account of instructions given at every situation was not being investigated. The idea was to attain a set of instructions, which could be compared to recommendations made. The first part of this section looks at the methods of displaying information and what was displayed. The second part looks at the system in use and how and when information was displayed.

The Display

The design of the visual display can be seen in figure 11.1 (this is a representation and not taken from the actual system itself).

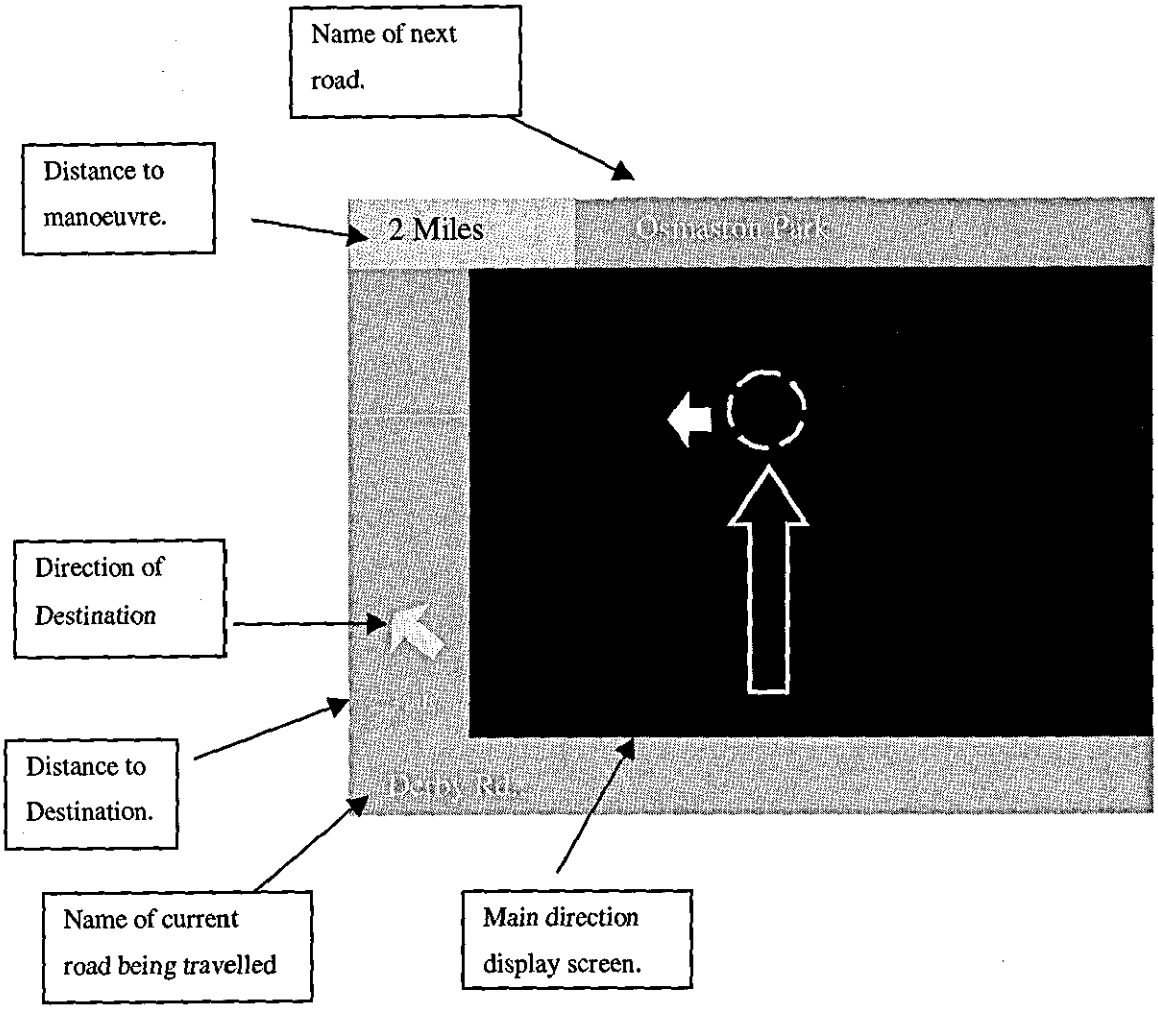


Figure 11.1: The visual display

The visual display consisted of a main screen for the display of directional and junction layout symbols, along with supplementary information displayed around the outside of the screen. This additional information included:

- *Distance to the manoeuvre/junction displayed on the main screen.* -This would count down e.g. 1mile..3/4 mile..1/2mile…300yds, as the manoeuvre/ junction was approached. This information was always present.

- *Direction of destination arrow* - This was a small arrow pointing in the general direction of the destination and was always present.
- *Distance to destination* - situated under the destination direction arrow, was the distance to the destination. Again this information was always present on the visual display.
- *Current road being travelled* - the name of the current road being travelled was always displayed at the bottom of the screen.
- *Next road to be travelled* - the name of the next road to be travelled was always displayed at the top of the screen.

Information was also given verbally using a female voice. Information given here included directional information, junction warning information and distance to turn information.

The interface in figure 11.1 is sound in a number of its features. Firstly the main screen employs a symbol-based system for the visual directions which through literature reviews was determined as best practice. Along with the visual information speech is also used, which again follows the recommendations made. Looking at the information displayed around the outside of the screen, it can be seen that some of this information is at the meso (e.g. distance to manoeuvre) and macro levels (distance to destination, current area of travel) defined in chapter 6. It was suggested in the recommendations that such information be permanently displayed to allow the driver to acquire the information when appropriate (i.e. when they have spare time and low mental workload). However no study was conducted to establish if this was good practice and so cannot be commented upon any further here.

The System In-Transit

To illustrate how the information was displayed to the driver during transit 2 scenarios are used. These scenarios are based on situations encountered during travelling the routes. These results focus on the directional symbols displayed on the main screen and the use of the voice information (the two main interests of this study). The other visual information described earlier was present at all times on the screen and so for simplicity is not included on the diagrams. Again all diagrams are representations and are not taken directly from the system.

Scenario 1

The first scenario deals with the car on an approach to a manoeuvre at a roundabout. The car has just turned right at a T-junction. Figure 11.2 presents the scenario along with the information provided to the driver both visually and verbally from this point to the next manoeuvre.

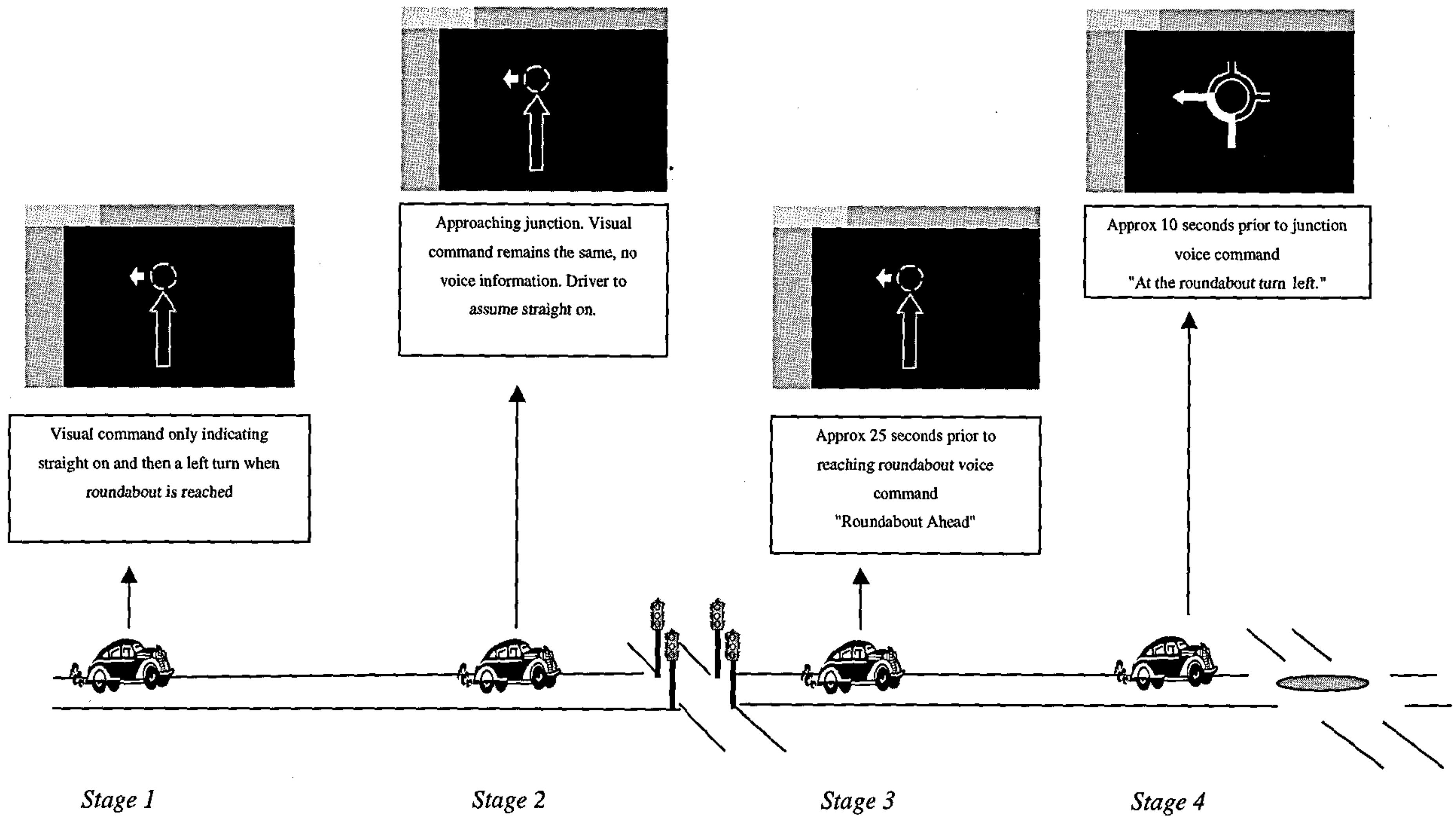


Figure 11.2: Scenario 1

Stage 1(figure 11.2)

Stage 1in figure 11.2 presents the first information displayed after turning onto the road. This is in the form of a large arrow, signifying to keep straight on. Above this arrow is a small circle and a smaller white arrow signifying that the next manoeuvre is to be a left turn at the roundabout. No voice information is provided to the driver.

The information provided to the driver here has a number of problems. After turning onto the road no verbal information is provided. Chapter 10 highlighted that a system should be employ primarily verbal instruction, especially in the case of older drivers due to distraction which can be caused by the screen. Therefore the screen should not change without verbal instruction.

It was clear from study 1 that drivers (especially older drivers), require some form of information after leaving a junction. With no verbal instruction they will have to look at the screen firstly to confirm whether they have made the correct manouvre and secondly to acquire information for the assessment process (such as distance they are to maintain their current path). This causes unnecessary distraction. A verbal instruction here would remedy the situation.

The content of the information displayed on the main screen at this stage could also cause confusion. Advanced information is being provided about the next manoeuvre in the form of what to turn at and which direction to turn (in the form of a circle and a small arrow). However prior to this manoeuvre there is a junction. This may cause confusion if the driver is not warned about the junction, and the circle is not identified as a roundabout (this will be highlighted in the next stage below). This is information being presented at the meso level (i.e. manoeuvre to manoeuvre) which was not recommended (see chapter 6) as most of the drivers operated at the micro level (i.e. junction to junction).

To remedy these problems a verbal instruction should be provided, indicating the driver is to continue along their current path for x number of miles *(e.g. "Follow road for 1 mile)*. The screen should display a single arrow to confirm this information, along with the distance displayed in large text on the main screen.

Stage 2 (figure 11.2)

Stage 2 in figure 11.2 shows the driver on the approach to a cross-roads. The visual information remains the same at this point, the driver is to assume to keep straight on. Again there is no voice information provided.

For older drivers there is a strong possibility of confusion here. In study 2 it was noted that when no voice information was given, any display information such as a turning arrow was picked up and acted upon by older drivers, without consideration of the junction the direction arrow was referring to. Thus they would take the next turn encountered. There is a possibility that the same confusion could arise here. The driver may take a left turn at the junction if only the directional information is picked up from the screen (i.e. they do not realise that the left turn arrow is indicating a manoeuvre at a roundabout not the approaching crossroads).

Again it is recommended that a route guidance system should use verbal information as its primary source of information. On seeing a junction this will prompt the driver to search information to establish what to do. Without verbal instruction this means the driver will have to look at the screen unnecessarily. Adding voice information here as outlined in the recommendations would remedy this situation. It is also suggested that the second arrow be removed as confusion could be caused if a voice instruction tells the driver to continue straight on and the driver has picked up left turn information from the screen. This is likely to cause conflicts especially for the older driver.

Stage 3 (figure 11.2)

Stage 3 in figure 11.2 shows the driver approximately 25 seconds away from the roundabout for which he/she must turn left. The visual screen at this point remains the same but there is some voice information warning of the approaching roundabout.

The first thing to note about stage three was that again no voice information was given after leaving the junction. As the driver nears the roundabout an auditory instruction is given. However the screen at this point does not change. In warning the driver of the approaching roundabout it is recommended that the screen represent the roundabout layout and provide an advanced turning instruction. The information provided here is a little earlier than preparatory information in the recommendations.

Stage 4 (figure 11.2)

Stage 4 in figure 11.2 shows the driver on the final approach to the roundabout. Once approximately 10 seconds away from the junction the screen changes to display the junction layout and a clearer directional arrow. There is also voice information provided at this point indicating which way the driver is to turn. Once the turn is made the system then moves back to stage 1 and the process repeated for the next manoeuvre/junction.

The information provided at this stage agrees with the recommendations in every way. The timing is the same as that recommended along with the content of the information and the presentation of the information.

Scenario 2

In this scenario the car has just left a junction and is travelling towards a cross-roads for which the driver must make a left turn. Prior to this manoeuvre there is a roundabout present. Figure 11.3 presents the scenario along with information displayed to the driver at varoius stages.

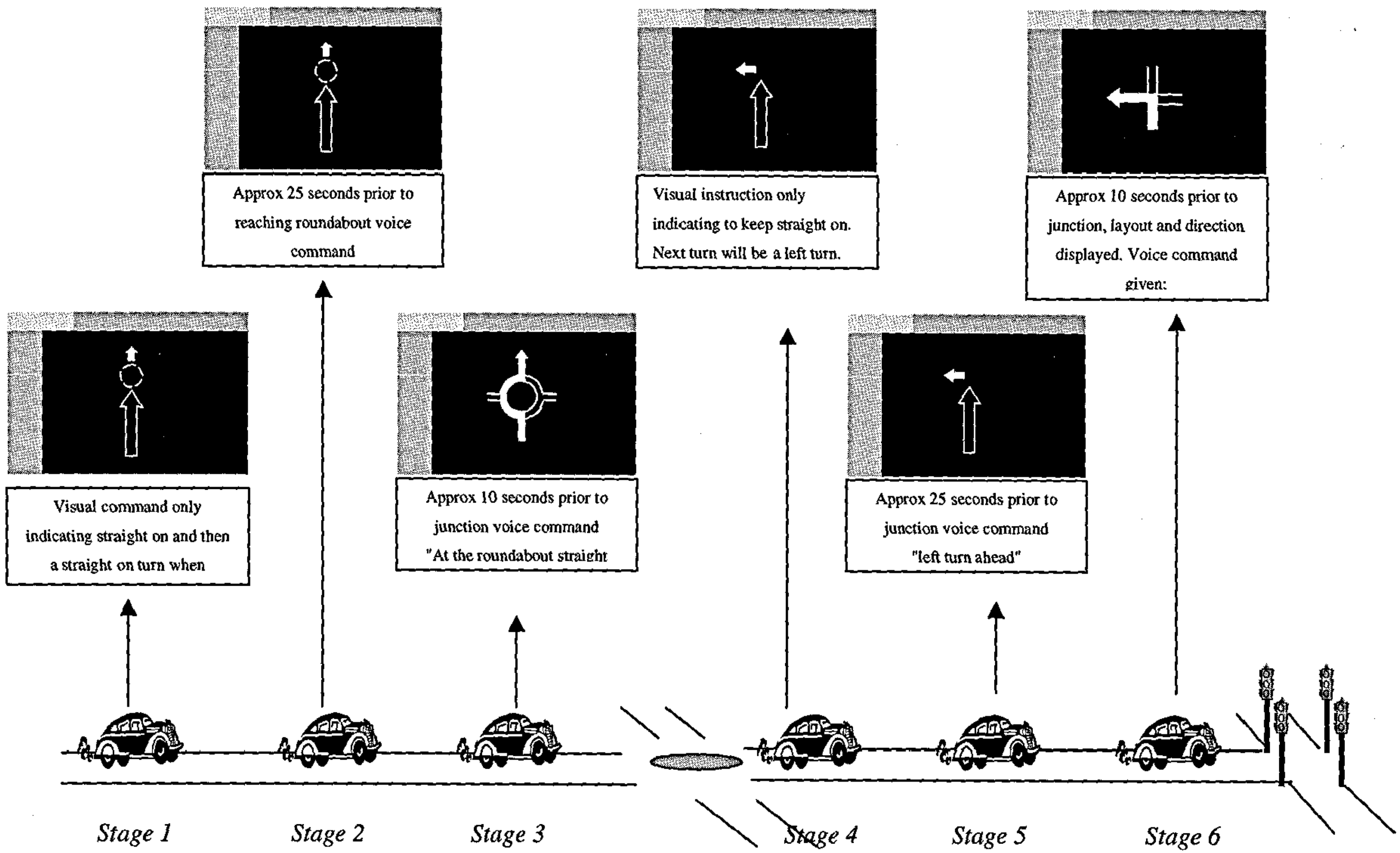


Figure 11.3: Scenario 2

Stage 1 (figure 11.3)

Stage 1 in figure 11.3 shows the information displayed after turning onto the road. The information is in the form of a large direction arrow indicating to keep straight on along with a small roundabout symbol above this and a second smaller white arrow indicating that the next manoeuvre will be straight on at a roundabout.

As with the previous scenario, no voice information is given when turning onto the new road though the screen changes. The problems here are the same as those mentioned in stage 1 of scenario 1 and so will not be repeated here. Added to this there is no reason why the guidance system at this stage should provide information on the approaching roundabout. It is not clear whether this is the next junction to be approached or not.

Stage 2 (figure 11.3)

Stage 2 in figure 11.3 shows the car approximately 25 seconds away from the roundabout. The visual screen remains the same but a voice instruction warning of the approaching roundabout is given.

As with the scenario 1 the first junction approached straight on manoeuvre. As this was a roundabout the system provided information on this junction. In the previous scenario the route guidance system ignored the first junction approached as it was not a roundabout. As recommended a route guidance system should provide information on all junctions approached to avoid confusion, and for confirmatory purposes.

Again the preparatory information given here (as with stage 3 in scenario 1) is given slightly earlier than the recommendations suggest. Again as with stage 3 in scenario 1 the screen information does not change. It is recommended at this stage that the layout of the junction be provided along with advance information on the direction to be taken.

Stage 3 (figure 11.3)

Stage 3 in figure 11.3 shows the car approximately 10 seconds away from the roundabout. The visual screen now changes to give a visual representation of the roundabout along with a larger direction arrow. A voice command indicating the direction to be taken is also given.

The information given at this stage agrees with the recommendations in every way from the timing to the content and presentation of information.

Stage 4 (Figure 11.3)

Stage 4 in figure 11.3 shows the car just completing the roundabout manoeuvre. The visual screen now changes showing a large transparent straight on arrow with a smaller white arrow above pointing left indicating the next manoeuvre. No voice command is given.

As mentioned previously a verbal instruction should be given here for confirmatory purposes and to give the driver some idea of the immediacy of upcoming events. Again this is crucial with respect to older drivers. Also the smaller white arrow should not be displayed. This is likely to lead to confusion, especially for older drivers for reasons mentioned in stages 1 and 2 of scenario 1.

Stage 5 (Figure 11.3)

Stage 5 in figure 11.3 shows the driver approximately 25 seconds from the crossroads. The visual screen remains the same but there is also a voice instruction warning of the approaching manoeuvre.

Again the information provided here is a little earlier than that suggested for preparatory information. The main problem here is the terminology used. 'Left turn approaching' suggests a side road rather than a junction. The system should simply indicate that a junction is approaching. Anything that wasn't a roundabout was nearly always referred to as a junction in study 1 (see chapter 6). This terminology was also used in study 2 and it seemed to be natural to the drivers (i.e. no one misunderstood). The screen at this point again displays a smaller white arrow to indicate the left turn, but there is no indication of what to turn left at from the screen or the voice instruction. Any side roads prior to this junction are likely to be mistaken for the manoeuvre which is required. Using the recommendations, these problems can simply be overcome. The preparatory verbal instruction should simply be 'Junction approaching'. The junction layout along with the turn information should then be displayed on the screen. The screen information thus gives the driver advanced warning of what is approaching and which way to turn, the driver being alerted to this by the voice instruction. This provides the driver with suitable information of what to turn at and which way to turn. As noted in study 2 older drivers are not confused with the arrow information when voice instructions accompany all screen information, as they wait for the verbal instruction to turn before acting on any information presented visually.

Stage 6 (figure 11.3)

Stage 6 in figure 11.3 shows the driver approximately 10 seconds from the junction. The visual screen now changes to show the junction layout and a large direction arrow is displayed. A voice command is also used to tell the driver the approximate distance to the manoeuvre. Once the manoeuvre the process is repeated depending on the next junction/manoeuvre to be encountered.

The visual information and timing at this stage fit well with the recommendations made for the execution stage. However there is a problem with terminology of the verbal instruction. As drivers a poor at judging distances the instruction 'turn left in 100 yards' should only be used when other methods for identify a turn are not available (e.g. when turning into a side road). The instruction 'turn left at the junction' would have clearly indicated to the driver where to turn, especially in the situation where other side roads were close to the junction.

11.5 Conclusions

This chapter set out the main recommendations from the two studies carried out in this thesis. These were used to evaluate a current commercially available route guidance system. Because the recommendations are of a detailed level they were easily applied to the evaluation process. It seems that route guidance systems still have some way to go to meet the needs of users, especially older drivers. One of the main problems is that the system evaluated did not use verbal instructions as its primary source of information. This is critical for older drivers due to the distraction caused by the screen. This was noticeable on leaving junctions, a stage at which older drivers were shown to require information. The system also appeared to work more at the meso level (i.e. manoeuvre to manoeuvre), rather than junction to junction, ignoring junctions in between manoeuvres (except for roundabouts). Study 1 in this thesis revealed that drivers tend to work from junction to junction. Even when working from manoeuvre to manoeuvre preparatory and confirmatory information was also sought for the junctions in between.

There were also positive aspects of the system evaluated. It was based on a combination display as recommended using simple voice commands, and symbol based visual display. The timings and content of the information at certain stages matched exactly the recommendations provided.

The changes highlighted for the system evaluated appear relatively simple and straight forward. This was because problems were easily identified due to the detailed recommendations this thesis set out produce. Many of these problems would not have been easily identified based on previous literature due to lack of detail and knowledge in this area.

Chapter 12: Thesis Conclusions

12.1 Chapter Summary

The previous chapters in this thesis have each had their own study specific conclusions and so will not be repeated here. The first part of this chapter provides a summary of the research and how each of the research aims stated in chapter 1 have been met. The second part of this chapter then highlights the contributions to knowledge this research has made. The third part of this chapter highlights the areas in which further work is required, before finishing with the final thesis conclusions.

12.2 Thesis Summary

This thesis examined issues surrounding older drivers, navigation and route guidance information. The emphasis was specifically on older drivers due to their increasing number and the problems they face in the navigation task compared to their younger counterparts (see chapter 2). It was argued that route guidance systems have the potential to benefit older drivers more than other driving populations, but only through good human factors practice in the design of such systems. This thesis aimed to maximise this potential by providing detailed human factors knowledge in this area so that route guidance systems can be designed to meet the needs of older drivers. The following sections review the aims of the thesis and how each of these has been met.

12.2.1 Content and Timing

The first aim was to investigate drivers strategies for real time navigation in an unfamiliar area identifying the content of navigational information used, the timing of this information and the differences between older an younger drivers. Literature revealed very little was known about any of these areas (see chapter 3). A field trial was conducted culminating in a model of the information requirements of drivers as they travel through unfamiliar areas (see chapters 4,5 & 6). Differences between older and younger drivers were also identified

The second aim here was then to identify that information that would be suitable for inclusion in a route guidance system aimed at older drivers. Using the model as a template for the content and timing of information suitable for a route guidance system, a set of recommendations were produced taking into account older driver needs (see chapter 6). It was highlighted here that due to the two age groups having many similarities, these recommendations would possibly be suitable for both.

12.2.2 Information presentation

The third aim of the thesis was to identify the most suitable presentation modality for the chosen route guidance information, identifying differences between older and younger drivers. A literature review (see chapter 7) identified that speech was the most suitable presentation format of auditory information, and symbols were the most suitable format for the presentation of visual information. The literature also highlighted that the best presentation modalities appeared to be either auditory alone or a visual-auditory combination. This however was by no means conclusive and very few of the studies had considered age. The second study was a lab trial set up to identify the best presentation modality across ages (see chapters 8, 9 & 10). This culminated in recommendations for the presentation of route guidance information taking into account age as a factor (see chapter 10).

12.2.3 Recommendations & Route Guidance System Evaluation

The fourth aim of this research was to produce a set of recommendations for the design of a route guidance interface suitable for the older driver. The recommendations from the field trial (study 1) and the laboratory experiment (study 2) were integrated to form a set of recommendations for a route guidance system (see chapter 11). Both of these studies had considered age as a factor and so the recommendations were particularly tailored for the older driver, though they also appeared to be suitable for younger drivers.

The final aim of the thesis was to use the proposed recommendations to evaluate a current commercially available route guidance system. This was to demonstrate the application of the recommendations, possible due to their detailed nature, and to assess the status of current route guidance systems in meeting the needs of the older driver. A number of deficiencies in the route guidance system evaluated were identified and recommendations for improvement made (see chapter 11).

12.3 Contributions to Knowledge

The contributions to knowledge effectively mirror the research aims. Literature revealed that there was a lack of knowledge in the some of the human factors issues surrounding route guidance systems (e.g. content and timing of information). Such knowledge was lacking for all drivers, and was virtually non-existent when considering the needs of older drivers. This section highlights the main contributions to knowledge made by this research.

Only two previous research studies had examined older drivers and navigation (i.e. Burns 1997; Burnett 1998). The main focus of these studies involving older drivers was based around information acquired from questionnaires. Study 1 of this thesis was conducted due to the lack of detailed knowledge in the information and timing needs of older drivers as they travel the real world environment. The methodology and analysis of data was developed to allow information to be collected at a more detailed level than previously incorporating the type of information asked for (e.g. ego-centred directions), the reference of this information (e.g. distance to destination, distance to junction), and the timing of this information. This is the first research that has produced a complete picture of this process for older drivers and at such a detailed level. This allowed for the development of a driver model which identified information requirements at three different levels. This contribution provides a template for the further development of route guidance systems. The recommendations provided in study 1 are the most complete and detailed thus far, not only for older drivers, but for all drivers. This provides human factors information at a level which can easily be applied by designers.

Study 1 also found differences in the information sought by drivers depending on whether they were given a map prior to driving or navigated 'blind'. When driving with a route guidance system it is conceivable that the driver will not look at a map prior to driving. Therefore understanding driver needs in the 'blind' navigation situation is crucial. Only one previous study (Daimon et al 1997) acquired information as the drivers navigated in this way. However study 1 provided a comparison of the two methods, which had not previously been made. The findings indicated that care is needed when suggesting the content and timing of route guidance systems based on trip planning information, or traditional methods of navigation (i.e. a map), as there are differences.

Concerning the presentation modality of route guidance information only one previous study had compared auditory only with a visual-auditory combination. However due to simulator sickness experienced by older drivers it was not possible to compare across ages in this study. Study 2 remedied this situation by employing a computer based experimental methodology. Some of the findings (e.g. the visual screen producing worse performance) were consistent with previous research and so produced validation of the method used. The differences between older and younger drivers were identified and recommendations for the older driver presented.

Chapter 11 brought the two sets of recommendations (from study 1 and study 2) together two to form a detailed set of recommendations on all of the main human factors issues concerning route guidance systems. This is the only work that has produced such a detailed set of recommendations. Such detailed recommendations do not exist for any of the driver populations let alone older drivers. It is believed that this is a big step forward in human factors knowledge concerning the development of route guidance systems especially for older drivers.

12.4 Further Work

Although this research has advanced human factors knowledge concerning route guidance systems and older drivers, such knowledge is far from complete. More work is required especially in the area of the content and timing of information. These two areas have been neglected. Although recommendations have been made in the present research corroboration is required. Further studies would be welcomed in identifying driver information needs and the timing of these needs not only for older drivers but all drivers. This would produce information which could be compared with the present research. Only in this way will patterns emerge and consistencies be identified allowing for definitive recommendations.

Further work is also required in the content and timing of route guidance information relative to complex junctions and side roads. Both of these situations were highlighted as potential problem areas that this research has not resolved. At complex junctions the use of exit information and signs (as suggested as a possible solution) needs to be investigated to identify the best means of providing navigational information to the driver. For side roads, again suggestions were made, but this requires further research into the possibility, for example, of using street names to help drivers locate the particular road they are to turn into.

The logical step following the research in this thesis would be to produce a prototype system based on the recommendations for trials in the real world environment. Even though study 2 (see chapters 8, 9 & 10) produced initial validation of the recommendations a field trial would be the only way to truly assess these recommendations and allow for their tailoring to meet the needs of older drivers or a particular driving population.

Route guidance information at the meso and macro levels of the driver model defined in chapter 6, also require further research. Some of the younger drivers in study 2 indicated that they would have liked more advance information on manoeuvres. It is possible that a system could provide options of different information levels depending on driver preferences (e.g. junction to junction, or manoeuvre to manoeuvre). Also recommendations based on information at the macro level of the driver model (e.g.

the driver's current position, location of the destination, distance to the destination), were only suggested based on the way the drivers used such information. This information was not incorporated into study 2, and so the content and presentation has not been validated

Concerning presentation modalities and the how drivers interact with current systems, changes are likely due to rapid advances in technology. More work is required on head up displays as this may reduce the distraction of the visual display (a major benefit for older drivers). Also it is possible that the interaction between the driver and the route guidance system could be voice controlled (e.g. the driver simply asks for any information required). This area certainly requires more work but the methodology applied in study 1 (see chapter 4) certainly provides a valuable insight into how this could possibly work (as 'question asking protocols' were employed).

12.5 Thesis Conclusion

From the research it is clear that older drivers have been neglected in terms of human factors research into route guidance systems. Due to their increasing numbers and the potential benefits such systems could provide, it is crucial that a full understanding of their needs in the navigation task is acquired. This research has advanced knowledge in this area by identifying driver needs for the content, timing and presentation of route guidance information suitable for the older driver.

References

References

AA (1988). *Motoring and the older driver.* Automobile Association, AA Foundation for Road Safety Research.

AA (1997) Living With the Car*: What drivers say. What drivers think. What we say needs to be done.* AA Policy Document

AA Foundation for Road Safety Research (1993). *Older Road Users: The Role of Government and the Professions.* Proceedings of a one-day conference, The royal Society of Arts, London, 19th November.

Akamatsu, M., Yoshioka, M., Imacho, N., Daimon, T., & Kawashima, H. (1997). Analysis of driving a car with a navigation system in an urban area. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 85-96). Mahwah, NJ: Lawrence Erlbaum Associates.

Alm, H. (1990). Drivers cognitive models of routes. In W. van Winsum, H. Alm, & J.M. Schraagen (Eds.), *Laboratory and Field Studies on Route Representation and Drivers Cognitive Models of Routes* Gronigen: Traffic Research Centre

Alm, H., Nilsson, L., Jarmark, S., Savelid, J., & Hennings, U. (1992). *The effects of landmark presentation on the driver performance and uncertainty in a navigation task*, (Nr 692A). VTI Swedish Road and Traffic Research Institute.

Ashby, M.C., Fairclough, S.H., & Parkes, A.M. (1991). *A comparison of two route information systems in an urban environment* (DRIVE I V1017 BERTIE, Deliverable 49). Loughborough, UK: HUSAT Research Institute.

Ashby, M.C., & Parkes, A.M. (1993). Interface design for navigation and guidance. In A.M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 295-310). London: Taylor and Francis.

Ball, K. & Owsley, C. (1991). Identifying correlates of accident involvement for the older driver. *Human Factors*, 33, 583-595.

Barr, R. A. (1991). Recent changes in driving among older adults. *Human Factors*, *33*, 597-600.

Bengler, K., Haller, R., & Zimmer, A. (1994). Experimental optimisation of route guidance information using context information. In *Proceedings of the First World Congress on Applications of Transport and Intelligent Vehicle Highway Systems*: Vol. 4. (pp. 1758-1765). Boston: Artech House.

Blades, M. (1993). Naviagtion and Wayfinding in Information Systems. *In Human Factors in GIS* (pp. 61-69)

Brouwer, W. H., Waterink, W., Van Wolffelaar, P. C., & Rothengatter, T. (1991). Divided attention in experienced young and old drivers: Lane tracking and visual analysis in a dynamic driving simulator. *Human Factors*, *33*, 573-582.

Brown, C. & Hook, K. (1993). A human view of dialogue and dialogue management in the automobile. In A.M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 295-310). London: Taylor and Francis.

Burnett, G.E., & Joyner, S.M. (1997). An assessment of moving map and symbol-based route guidance systems. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 115-136). Mahwah, NJ: Lawrence Erlbaum Associates.

Burnett, G.E. (1998). "Turn right at the King's Head" Drivers' requirements for route guidance information. *Unpublished Phd Thesis*, Loughborough University, UK

Burnett, G.E., & Parkes, A.M. (1993). The benefits of "Pre-Information" in route guidance systems design for vehicles. In E.J. Lovesey (Ed.) *Contemporary ergonomics* (pp. 397-402). London: Taylor and Francis.

Burns, P.C. (1997). Navigation and the older driver. *Unpublished PhD dissertation,* Loughborough University, UK.

Byers, J. C., Bittner, A. C., & Hill, S. G. (1989). Traditional and raw Task Load Index (TLX) correlations: are paired comparisons necessary? In I. A. Mital (Ed.), *Advances in Industrial Ergonomics and Safety* (pp. 481-485).

Charman, W.N. (1997). Vision and driving – a literature review and commentary. *Opthal. Physiol. Opt.* 17(5), pp. 371-391.

Daimon, T., Kawashima, H., & Akamatsu, M. (1997). Drivers' Cognitive Process and Route Guidance. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 115-136). Mahwah, NJ: Lawrence Erlbaum Associates.

Dingus, T.A., & Hulse, M.C. (1993). Some human factors design issues and recommendations for automobile navigation information systems. *Transportation Research,* IC(2), 119-131.

Eby, D.W., & Kostyniuk (1999). An On-the-Road Comparison of In-Vehicle Navigation Assistance Systems. *Human Factors,* 42, 295-311

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors*, 37(1), 32-64

European Road Safety Federation (1997). The Safety of Older Drivers in the European Union. *ERSF*

Evans, L. (1994). The older driver problem: an epidemiological overview. In *Enhanced Safety of Vehicles Conference*, (pp. 1-10). Munich: SAE.

Fairclough, S.H. (1991). *Adapting the TLX to assess driver mental workload* (DRIVE I V1017 BERTIE, Deliverable 71). Loughborough, UK: HUSAT Research Institute.

Fairclough, S. H., Ashby, M. C., Ross, T. and Parkes, A. M. (1991). Effects of handsfree telephone use on driving behaviour. *Proceedings of the ISATA Conference*, Florence, Italy.

Fairclough, S. H., Ashby, M. C., & Parkes, A. M. (1993). In-vehicle displays, visual workload and usability evaluation. In A. G. Gale (Ed.), *Fourth International Conference on Vision in Vehicles*, (pp. 245-254). Amsterdam: Elsevier.

Fairclough, S. H., Ashby, M. C., & Parkes, A. M. (1993). In-vehicle displays, visual workload and usability evaluation. In A. G. Gale (Ed.), *Fourth International Conference on Vision in Vehicles*, (pp. 245-254). Amsterdam: Elsevier.

Federal Highway Administration (1995). *Spatial ability and advanced traveller information system route guidance*. FHWA-RD-95-125.

Fildes, B., & Lee, S. (1994). Older road user problems on urban roadways. In IEA (Ed.), *12th Triennial Congress of the International ErgonomicsAssociation, 6* (pp. 193-195). Toronto: IEA.

Galer, G. D. (1984). Human factors in the design and assessment of in-vehicle information systems. *Int. J. of Vehicle Design*, Special Issue on Vehicle Safety. pp. 338-343

Galer Flyte, M.D. (1995). The safe design of in-vehicle information and support systems: The human factors issues. *International Journal of Vehicle Design*, 16 (2/3), 158-169.

Gärling, T., & Golledge, R.G. (1989). Environmental perception and cognition. In E.H. Zube and G.T. Moore (Eds.) *Advances in environment, behaviour and design* (pp. 203-236). New York: Plenum.

Green, P., & George, K. (1995). When should auditory guidance systems tell drivers to turn? In *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting*: Vol. 2. (pp. 1072-1076). Santa Monica, CA: Human Factors and Ergonomics Society.

Green, P., Williams, M., Hoekstra, E., George, K., Wen, C. (1993b). *Initial on-the-road tests of driver information system interfaces: route guidance, traffic information, IVSAWS, and vehicle monitoring* (Tech. Rep. No.UMTRI-93-32). Ann Arbor, MI: University of Michigan TransportationResearch Institute

Green, P., Levison, W., Paelke, G., & Serafin, C. (1995). *Preliminary human factors design guidelines for driver information systems* (Tech. Rep. No. FHWA-RD-94-087). Washington, DC: U.S. Government Printing Office.

Guerrier, J.H., Manivannan, P., Nair, S.N. (1999). The Role of Working Memory, Field Dependence, Visual Search, and Reaction Time in the Left Turn Performance of Older Female Drivers. *Applied ergonomics*, 30, 109-119.

Hakamies-Blomqvist, L. (1988). *Fatal Road Accidents Involving Elderly Drivers.* Paper presented at the Commision of European Communities Workshop on errors in the Operation of Transport Systems, Cambridge.

Hancock, P. A., Dewing, W. L., & Parasuraman, R. (1993, The human factors of intelligent travel systems. *Ergonomics in Design*, p. 12-39.

Hartson, H.R. (1985) *Advances in Human-Computer Interaction.* Volume 1. Ablex Publishing Coorporation.

Hauer, E. (1988). The safety of older persons at intersections. In *Transportation in an Ageing Society, Vol 2, Improving Mobility and Safety for Older Persons.* TRB, NRC, Washington, DC,USA

Howell, D.C. (1997). *Statistical Methods for Psychology (4th edition).* Duxbury Press.

James, C.L. & Ehret, B.D. (1993). Effect of Advanced Traveller Information Systems (ATIS) Display View and Age on Intersection recognition. *Internet Paper*: http://www.hfac.gmu.edu/People/Behret/pubs/93hfes.html.

Janssen, W. H. (1979). *Routeplanning en geleiding: een literatuurst*udie, Soesterberg, The Netherlands: TNO Institute for Perception.

Japenese Ministry of Transport (1998). Press Release, November 18th.

Jeffery, D. J. (1981). *Ways and Means for Improving Driver Route Guidance*, (1016). Transport and Road Research Laboratory.

Kaszniak, A. W., Keyl, M., & Albert, M. S. (1991). Dementia in the older driver. *Human Factors*, *33*, 527-538.

Kato, T. (1986). What 'question asking protocols' can say about the user interface. *International Journal of Man-Machine Studies*, Vol. 25, pp. 659-673

King, G. F. (1986). Driver performance in highway navigation tasks. *Transportation Research Board*, *1093*, 1-10.

Kishi, H., & Sugiura, S. (1993). Human factors considerations for voice route guidance (SAE Tech. Paper Series 930553). Warrendale, PA: Society of Automobile Engineers.

Klien, R. (1991). Age-related eye disease, visual impairment, and driving in the elderly. *Human Factors*, *33*, 521-526.

Kline, D.W., Buck, K., Sell, Y., Bolan, T.L., & Dewar, R.E. (1999). Older Observers' Tolerance of Optical Blur: Age Differences in the Identification of Defocused Text Signs. *Human Factors,* 41, 356-364.

Konstantinos, K.V., Yawa D, Fisher, D.L. & Duffy, S.A. (2000). The framing of drivers route choices when travel time information is provided under varying degrees of cognitive load. Human Factors, 42, 470-481

Kosnik, W. D., Sekuler, R., & Kline, D. W. (1990). Self-reported visual problems of older drivers. *Human Factors*, *32*, 597-608.

Kuipers, B.J. (1978). Modelling spatial knowledge. *Cognitive Science*, 2, 129- 153.

Kuipers, B.J. (1982). The "map in the head" metaphor. *Environment and Behaviour*, 14, 202-220.

Labiale, G. (1989). *Influence of in car navigation maps displays on drivers performances*, (891683). SAE.

Lamble, D. Laakso, M., Summala, H. (1999). Detection thresholds in car following situations and peripheral vision: implications for positioning of visually demanding in-car displays. *Ergonomics,* 42, 807-815.

Lansdale, M.W., Ormerod, T.C. (1995). *Understanding Interfaces: a handbook of human-computer dialogue*. Academic Press

Lansdown, T. C., & Burns, P. C. (1997). Route Guidance Information: Visual, Verbal or Both? In *International Ergonomics Association, 13th Triennial Congress*, Tampere, Finland: IEA.

Lynch, K. (1960). *The Image of the City*. London: M.I.T. Press.

Mark, D.M. (1993). Human Spatial Cognition. In D.Medyckyj-Scott & H.M.Hearnshaw (Eds), *Human Factors in Geographical Information Systems* (pp.51-60). London: Belhoven Press.

Malaterre, G. & Fontaine, H. (1993). In A.M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 157-170). London: Taylor and Francis.

Malfetti, J. & Winter, D. (1987) *Safe and Unsafe Performance of Older Drivers: a descriptive study*. AAA Foundation for Traffic Safety, Falls Church, VA, USA.

Nicolle, C. (1995). Design Issues for Older Drivers. *Ergonomics in design*, 14-18.

Olsen, P.L. (1993). Vision and Perception. In B. Peacock & W. Karwowski (Eds), *Automotive Ergonomics* (pp. 161-184). London: Taylor & Francis

Oxley, P., & Mitchell, K. (1995). *Final Report on Elderly and Disabled Drivers Information Telematics*, Deliverable (EC Drive II project V2031). Cranfield.

Parasuraman, R., & Nestor, P. G. (1991). Attention and driving skills inaging and alzheimers disease. *Human Factors*, *33*, 539-572. Parker, D., Reason, J. T., Manstead, A. S. R., & Stradling, S. G. (1995). Driving errors, driving violations and accident involvement. *Ergonomics*, *38*, 1036-1048.

Parkes, A.M. (1991). Data Capture Techniques for RTI usability evaluation. In *Advanced Telematics in Road Transport Vol II.* Proceedings of DRIVE conference, Brussels (pp. 1440-1456). Amsterdam: Elsevier

Passini, R. (1984). Spatial representations, a wayfinding perspective. *Journal of Environmental Psychology*, 4, 153-164.

Pauzie, A., & Anadon, S. (1993). Visual requirements of vehicle guidance systems: central versus peripheral preparatory information display. In A. G. Gale (Ed.), *Vision in Vehicles* V, Glasgow: Elsevier.

Pauzie, A., & Letisserand, D. (1992). Ergonomics of MMI in aid driving systems: approach focusing on elderly visual capacities. In B. Bouman & J. A. M. Graafmans (Eds.), *Gerontechnology: Studies in health technology and informatics* (pp. 329-334). Oxford: IOS Press.

Pembroke, J. (1997) The Years of Driving Dangerously. *The Guardian*. Thursday, January 16th (pp. 20-21)

Planek, T. W. (1981). The effects of ageing on driving abilities, accident experience, and licensing. In H. C. Foot, Chapman, A.J. and Wade, F.M. (Eds.), *Road Safety: Research and Practice* London: Praeger Publishers.

Rabbitt, P.M.A. (1996) cited in AA (1997) Living With the Car*: What drivers say. What drivers think. What we say needs to be done.* AA Policy Document

Rabbit, P.M.A., & Holland, C.A. (1994). The problems of being an Older Driver: comparing the perceptions of an expert group and older drivers. *Applied ergonomics*, 25(1), 17-25

Rabbitt, P., Carmichael, A., Jones, S., & Holland, C. (1996). *When and why older drivers give up driving*. AA Foundation for Road Safety.

Rockwell, T. (1972). Skills, judgement, and information acquisition in driving. In T.Forbes (Ed), *Human factors in highway traffic research* (pp. 133-164). New York: Wiley Interscience.

Ross, T. (1993). Creating new standards: the issues. In A.M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 295-310). London: Taylor and Francis.

Ross, T., Vaughan, G., Nicolle, C. (1997). Design guidelines for route guidance systemsL development process and an empirical example for timing of guidance instructions. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 115-136). Mahwah, NJ: Lawrence Erlbaum Associates.

Rothengatter, J.A. (1995). Designing In-Vehicle Interaction to Meet User Requirements: The Value of Human Factors. In J.P. Pauwelussen & H.B. Pacejka (Eds) *Smart Vehicles* (pp. 388-392) Swets & Zeitlinger Publishers.

Rumar, K. (1988). Collective risk but individual safety. *Ergonomics*, 31, 4, 507-18

Satalich, G. A. (1997). Navigation and Wayfinding In Virtual Reality: Finding Proper Tools and Cues to Enhance Navigation Awareness. *Internet Paper*: http://www.hitl.washington.edu/publications/satalich/ref.html

Schlag, B. (1993). Elderly drivers in Germany: Fitness and driving behavior. *Accident Analysis and Prevention*, 25, 47-55

Schraagen, J. M. C. (1990). *Strategy Differences in Map Information use for Route Following in Unfamiliar Cities: Implications for In-Car Navigation Systems*, (IZF 1990 B-6). TNO Institute for Perception.

Schraagan, J. M. C. (1991). *An experimental comparison between different types of in-car navigation information.* Report IZF 1991 B-1, Soesterberg, The Netherlands

Schraagen, J. M. C. (1993). Information presentation in in-car navigation systems. In A. M. Parkes & S. Frazen (Eds.), *Driving Future Vehicles* (pp. 171-186). London: Taylor & Francis.

Shinar, D., & Schieber, F. (1991). Visual requirements for safety and mobility of older drivers. *Human Factors*, *33*, 507-520.

Shneiderman, B. (1992) *Designing the User Interface.* Addison-Wesley Publishing Company

Sivak, M. & Flannagan M. (1993). Human Factors considerations in the design of vehicle headlamps and signal lamps. In B.Peacock & W. Karwowski (Eds), *Automotive Ergonomics* (pp.185-204). London: Taylor and Francis.

Sixsmith, J. (1990). *Driving experiences & new technology: evaluations and expectations of older drivers*, (Occasional Paper No. 30). EC Drive Programme.

Sixsmith, J., & Sixsmith, A. (1993). Older people, driving and new technology. *Applied Ergonomics*, 24, 40-43.

Smith P.A. (1986). Vision and Driving. In A.G.Gale et al. (eds), *Vision in Vehicles* (pp.13-17). Elsevier Science Publishers B.V. (North Holland)

Srinivasan, R., & Jovanis P. (1997). Effect of Selected In-Vehicle Route Guidance Systems on Driver Reaction Times. *Human Factors*, 39(2), 200-215

Srinivasan, R., & Jovanis P. (1997). Effect of In-Vehicle Route Guidance Systems on Driver Workload and Choice of Vehicle Speed: Findings from a driving simulator experiment. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 115-136). Mahwah, NJ: Lawrence Erlbaum Associates.

Stelmach, G.E. & Nahom, A. (1993). The effects of age on driving skill cognitive-motor capabilities. In B.Peacock & W. Karwowski (Eds), *Automotive Ergonomics* (pp.185-204). London: Taylor and Francis.

Streeter, L. A., Vitello, D., & Wonsiewicz, S. A. (1985). How to tell people where to go: comparing navigational aids. *International Journal of Man-Machine Studies*, 22, 549-562.

Streeter, L.A., & Vitello, D. (1986). A profile of drivers' map-reading abilities. *Human Factors*, 28 (2), 223-239.

Streff, F. M., & Wallace, R. R. (1993). Analysis of drivers information preferences and use in automobile travel: implications for advanced traveller information systems. In *Vehicle Navigation and Information Systems Conference VNIS93*, (pp. 414-418). Ottawa: IEEE-IEE.

Sussman, E.D., Bishop, H., Madnick, B. & Walter, R. (1985). Driver inattention and highway safety. *Transportation Research Record*, 1047, 40-8-

Sutcliffe, A.G. (1995). *Human-Computer Interface Design*. Macmillan Press Limited.

Theeuwes, J. & Godthelp, H. (1995). Self-Explaining Roads. *Safety Science*, 19, 217-225

Tolman, E.C. (1948). Cognitive maps in rats and men. *Psychological Review*, 55, 189-208.

Treat, J. R., Tumbas, N.S., McDonald, S.T. (1979). *Tri-level study of the causes o traffic accidents: Final report* (Vol. 1 and 2) U.S. DOT HS-805-086, (NTIS PB 80-121064).

Verwey, W.B. (1993). Further evidence for benefits of verbal route guidance instructions over symbolic spatial guidance instructions. *In Proceedings of Vehicle Navigation and Information Systems* Conference (pp. 227-231). Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Verway, W.B. (2000). On-line Driver Workload Estimation. Effects of Road Situation and Age on Secondary Task Measures. *Ergonomics*, 43, 187-209

Verwey, W. B., & Janssen, W. H. (1988). *Route following and driving performance with in-car route guidance systems*, (Report IZF 1988 C-14). TNO Institute for Perception.

Walker, J., Alicandri, E., Sedney, C., & Roberts, K. (1991). In-vehicle navigation devices: effects on the safety of driver performance. *SAE Transactions*, *912793*, 499-525.

Ward, S.L., Newcombe, N., & Overton, W.F. (1986). Turn left at the church or 3 miles north - a study of direction giving and sex differences. *Behaviour and Environment*, 18 (2), 192-213.

Warnes, A. M. (1992). Elderly people driving cars: issues and prospects. In K. Morgan (Ed.), *Gerontology Responding to an Ageing Society* (pp.14-32). London: Jessica Kingsley.

Warnes, A.M., Fraser, D.A., Hawken, R.E. & Sievey, V. (1993). Elderly drivers and new road transport technology. In A.M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 99-117). London: Taylor and Francis.

Warnes, A.M., Rough, B., Sixsmith, J. (1991). Factors in Elderly Peoples Driving Abilities: Elderly Drivers and New Technology. *DRIVE Programme*, Project V1006, DRIVAGE, Department of Geography, Kings College, London.

Wickens, C.D. (1980). The Structure of Attention Resources. In R.Nickerson (Ed), *Attention and Performance VIII*. Hillsdale,N.J:Erblaum.

Wickens, C.D. (1984). *Engineering Psychology and Human Performance*. Columbus, Ohio: Merill.

Wickens, C.D., Gorden, S.E., Liu, Y. (1997). *An Introduction to Human Factors Engineering*. Addison Wesley Longman Inc.

Wierwille, W. W., Antin, J. F., Dingus, T. A., & Hulse, M. C. (1988). Visual attentional demand of an in-car navigation display system. In a. M. H. F. A.G. Gale (Ed.), *Vision in Vehicles - II*, (pp. 307-316).

Wierwille, W. W. (1990). A review of the age effects in several experiments on instrument panel task performance, *SAE Transactions, 900190*.

Wierwille, W. W. (1993). Demands on driver resources associated with introducing advanced technology into the vehicle. *Transportation Research:* C, 1, 133-142.

Winsum, W. van, (1987). *De mentale belasting van het navigeren in het verkeer*. VK, 87-3

Wochinger, K., & Boehm-Davis, D. (1997). Navigational preference and driver acceptance of advanced traveler information systems. In Y. Ian Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 345-362). Mahwah, NJ: Lawrence Erlbaum Associates.

Zhao, Y. (1997). *Vehicle location and navigation systems.* Boston: Artech House.

Appendix 1

NASA R-TLX Rating Scale for Study 1

Driving Trial

Driver Questionnaire

Subject Number ☐☐☐☐

Date ☐☐ ☐☐ ☐☐

Time ☐☐. ☐☐ am/pm

Personal Details

		Male	Female	
1	Sex	☐	☐	
	Height	______________		
		Day	Month	Year
2	Date of Birth	☐☐	☐☐	☐☐
3	Number of years driving license held	Years ☐☐		
4	Number of years regular driving	Years ☐☐		
5	Annual Mileage/km (approx)	Miles/km ☐☐☐☐☐		

Driving is 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 relation to other vehicles, control position on the road via the steering wheel while 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 practice 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 following breaks down the driving task into six distinctive components. Please read through the descriptions of each factor and inform the experimenter when you have finished.

Mental Demand
This factor refers to any mental demand **placed on you** by the driving task e.g. in planning thinking, deciding, remembering, looking or searching. Was the driving task mentally easy or demanding?

Mental Effort
This factor refers to the mental effort **required by you** to maintain a safe level of driving. During the course of the journey how much concentration was required?

Physical Demand
This factor refers to any **physical activity** you have just experienced while driving, e.g. operating the car's controls and displays etc.

Time Pressure
This factor refers to how **hurried or harassed** you felt while driving e.g due to the presence of other vehicles, traffic flow, etc.

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 out side the vehicle. Sources both inside and outside the car have the potential to distract you from the driving task.

Stress Level
Ideally you should feel relaxed and unworried while driving. However circumstances may cause you to feel stressed, i.e. annoyed, frustrated, worried and/ or irritated. This factor refers to how **relaxed or stressed** you felt while driving.

Please place a mark through each line to show the amount that each factor applied to YOU.

For example, if you felt that your response was high, you would place a cross as shown below.

	Low	High
Example	├───────────────	───────────✘┤

	Low	High
Mental Demand	├	┤
Mental Effort	├	┤
Physical Demand	├	┤
Time Pressure	├	┤
Distraction	├	┤
Stress Level	├	┤

Appendix 2

Questionnaire for Study 2

Adapted NASA-R-TLX Rating Scale

Participant Number ☐☐☐☐ *Condition* ☐☐

The following breaks the tasks you have performed into five distinctive components. Please read through the descriptions of each factor and place a mark through each line to show the amount that each factor applied to YOU.

Mental Demand
This factor refers to any mental demand **placed on you** by the tasks e.g. thinking, deciding, remembering, looking or searching. Was it mentally easy or demanding?

Mental Effort
This factor refers to the mental effort **required by you** to maintain performance on the tasks. During the course of the journey how much concentration was required?

Physical Demand
This factor refers to any **physical activity** you have just experienced while performing the tasks e.g. operating the keyboard, looking at displays etc.

Time Pressure
This factor refers to how **hurried or harassed** you felt while performing the tasks e.g due to the rate at which the car was moving.

Distraction
This factor refers to the extent to which you felt **distracted** from the tasks by the information (visual and/or auditory) being presented to you.

Stress Level
Ideally you should feel relaxed and unworried while performing the task. However circumstances may cause you to feel stressed, i.e. annoyed, frustrated, worried and/ or irritated. This factor refers to how **relaxed or stressed** you felt whilst performing the task.

Please place a mark through each line to show the amount that each factor applied to YOU.

For example, if you felt that your response was high, you would place a cross as shown below.

	Low	High
Example		X

	Low	High
Mental Demand		
Mental Effort		
Physical Demand		
Time Pressure		
Distraction		
Stress Level		

Navigation Instructions Rating

1) Ideally instructions given by the navigation system should be clear, relevant and easy to follow. How would you rate the content of the navigational information received i.e. *What* was said or displayed.

Very Poor | Very Good

What **did** you particularly like about what was said/ displayed

....

....

....

....

What **didn't** you particularly like about what was said/ displayed

....

....

....

....

2) Ideally instructions given by the navigation systems should timely (instructions not given too early or given too late). How would you rate the timing of the navigational information received i.e. *When* it was said/displayed

Very Poor　　　　　　　　　　　　　　　　　　　　　　Very Good

What **did** you particularly like about when information was said/ displayed

....

....

....

....

What **didn't** you particularly like about when information was said/ displayed

....

....

....

....

3) Is there anything you would add to, or change about the navigational instructions

given? YES / NO

If YES Please Explain:

....

....

....

....

4) Please rate how clearly you could hear the voice information (if present).

Very Unclear Very Clear

5) Please rate how clearly you could see the visual information (if present)

Very Unclear Very Clear