Navigation and the Ageing Driver

by

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Abstract

This thesis examines issues surrounding route navigation. Emphasis is on the problems of elderly motorists. Elderly drivers have been said to avoid unfamiliar routes and may have wayfinding problems, but the extent and nature of these problems have not previously been investigated. This thesis aims to determine how drivers plan their routes and find their way in transit. It also seeks to investigate the prevalence and types of driver wayfinding problems, as well as their causes, consequences and psychological implications. Lastly, this thesis aims to measure the impact wayfinding problems have on mobility and identify potential solutions.

Three studies were conducted, the first was a preliminary investigation into route navigation issues. Focus group discussions explored driver wayfinding strategies and problems. The second study consisted of a postal questionnaire survey of motorists. Results suggested the most common route planning method was to read a map and take notes of the route. For wayfinding on major roads, drivers stated a preference for road number, place name, and junction information. In cities, they requested information about street names, lane position and landmarks. More drivers under 60 years of age preferred landmark information than did elderly drivers. The most frequent wayfinding errors were: missing a road sign, choosing the wrong lane, and detecting a sign or a turn too late to respond safely. The most frequently reported causes of wayfinding errors were: insufficient, inaccurate, obscured or non-existent traffic signs; inattention or distraction; inaccurate directions; darkness; busy roads and road repairs. As hypothesised, elderly drivers reported more difficulties with wayfinding and this was related to reduced mobility.

The third study explored different means of presenting route guidance information. An experiment was conducted to investigate the safety and efficiency of visual, auditory (speech) or a combined visual-auditory display. Driver performance, visual behaviour, subjective mental workload and preferences were recorded. For displaying simple route guidance information to drivers across ages, it is recommended that verbal displays be used as a primary source of guidance information and visual displays as a redundant reminder.

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Chapter 1: Introduction

1.1. Chapter Summary

This chapter introduces the research issues that are investigated in the thesis. It begins by describing some of the advantages and disadvantages of in-vehicle route guidance technology. Concerns are raised about the impact this technology may have for elderly motorists. This highlights a need to know more about the navigational requirements of drivers. It is identified that elderly drivers may be vulnerable to navigation problems and these difficulties may threaten their mobility. The aims of the thesis are described and their rationale is provided. A summary of the thesis structure is also given.

1.2. General Introduction

In-vehicle route guidance systems are intended to assist driving. These systems guide drivers to their destination with real-time procedural instructions (Ashby & Parkes, 1993). The increased navigational efficiency of route guidance systems could reduce travel time, distance driven and help drivers avoid congested routes. They could also reduce the number of drivers getting lost and have a potential to improve road safety (van Winsum, 1993). Further, it has been suggested that wayfinding in an unfamiliar environment is one of the most mentally demanding driving tasks (Streeter & Vitello, 1986). In-vehicle route guidance could improve road safety by reducing demands on drivers. These systems could lower demands by reducing drivers' need to actively search the environment for wayfinding information.

These route guidance systems also have potential limitations, especially with respect to elderly users. The problem is that route guidance was, and is being, created primarily with the motivation to create applications for new technology (e.g., global positioning satellite; Owens, Helmers, & Sivak, 1993). This technology driven approach often gives little consideration to the characteristics and needs of users. This neglect raises concern because the technology may impede instead of assist driving. Increasing the complexity of the driving task will create problems for all drivers but may have a more serious impact on elderly drivers. Elderly drivers, with their reduced physical and information processing abilities, may become overloaded during an already difficult and complicated task by the additional demands of a route guidance system (Stamatiadis, 1993). Concern that route guidance technology may threaten driver safety was the initial impetus for this thesis.

If route guidance systems are to be designed safely, the characteristics and needs of the users have to be identified. Specific issues are how to effectively display information to people without causing unsafe distraction from the driving task (e.g., what guidance information should be displayed, and where, when and how should it be displayed?). A review of the literature revealed that very little is known about how to display route guidance information. Issues relating to how to safely display route guidance information cannot be resolved without an understanding of what information is actually needed by drivers. An examination of the research on navigation and driving showed that even less was known about what information drivers' need to navigate successfully. As a consequence, the focus of the thesis widened to study the navigational needs of drivers.

Navigation involves route planning and wayfinding. Route planning is the navigational preparations people make before driving an unfamiliar route. Wayfinding refers to the decision making process that is required to negotiate a route to a destination. Very little is known about this part of driving. In order to understand navigational information needs, the current methods people use to plan their routes and find their way while driving must be examined. An understanding of the problems experienced while using these methods should also provide insight into what drivers need to navigate successfully.

Successful navigation is critical to driving. The main purpose for driving, in most cases, is to safely, conveniently and independently travel from one point to another. The potential consequences of navigation problems are wide ranging. They may have implications for road safety (Rothe, Cooper,

& de Vries, 1990), and could contribute to wasted time, inefficient fuel use and traffic congestion (Jeffery, 1981; King, 1986). They may also cause drivers undue stress and embarrassment.

The media has provided some extreme incidents of how navigation can go wrong. Two newspaper stories provide examples. "An old age pensioner was dragged from his car, robbed and beaten to death when he stopped to ask for directions..." (Alderson, 1996, p. 1). Similar violent episodes have appeared in the U.S.A. where "Oakland police say a fight between two brothers over directions resulted in one brother shooting the other in the head" (San Francisco Examiner, 1996).

Aside from these rare criminal events, getting lost is the worst navigation problem. Lynch (1960) has described some of what this entails:

> *"To become completely lost is perhaps a rather rare experience for most people in the modern city. We are supported by the presence of others and by special way-finding devices: maps, street numbers, route signs, bus placards. But let the mishap of disorientation once occur, and the sense of anxiety and even terror that accompanies it reveals to us how closely it is linked to our sense of balance and well-being. The very word 'lost' in our language means much more than simple geographical uncertainty; it carries overtones of utter disaster."* p. 4.

One of the main focuses of this thesis is the relationship between navigation problems and driver mobility. Navigation problems could have severe implications as the car is the most common means of personal mobility (Department of Transport, 1994). Difficulty in finding your intended destination decreases the functionality of this form of transportation and threatens the mobility of its users. An important feature of mobility is that it contributes to peoples' well being. Well-being is dependent on fulfilment of needs and mobility is a means to fulfilling these needs (Carp, 1988). Reduced mobility has been identified as a particular concern for elderly drivers. That is, "Unless transportation is devised to support mobility during retirement, this increasing segment in the life history of many persons will be one of loneliness and inactivity rather than one of self-fulfilment and social contribution" (Carp, 1971, p.191).

There has recently been an escalation in the amount of interest in elderly drivers. This has been prompted by increasing population and travel trends. Elderly people are driving more and the population of elderly motorists is increasing (e.g., Rosenbloom, 1993). Concern has been expressed about the safety implications of these trends because they constitute a high-risk component of the driving population (Waller, 1991). Difficulties in navigating may be one factor that increases the safety risk of elderly drivers. Navigation difficulties were the most widely mentioned of three main problem areas identified in discussion groups with elderly drivers (Sixsmith, 1990). These problems are probably attributable to the ageing process rather than generational differences. This thesis attempts to demonstrate that age related declines in physical and information processing abilities make the task of navigation more difficult for elderly drivers.

Although the emphasis of this thesis is on elderly drivers, it considers drivers of all age groups. Some have said: "Design for the young and you exclude the old. Design for the old and you include the young" (Nayak, 1995, p. 8). This is not true in all respects. Elderly people may have very different needs. Cohort differences alone make this motto unreasonable. For example, the differences in life experience or knowledge across ages could make designs based on the needs of the older person unusable for a younger person.

1.3. Research Aims

The general aims of this research are to investigate the navigation strategies people employ, and develop a model of driver wayfinding. It also aims to identify the types and causes of navigation problems and assess their impact on mobility.

The specific objectives are as follows:

1. Propose a theory to describe the process of route navigation and account for errors in wayfinding.

2. Find out how drivers currently navigate.

3. Measure the prevalence of navigation problems amongst the driving population, with particular emphasis being placed on elderly drivers.

4. Determine the types of navigation problems drivers encounter, as well as their causes, consequences and psychological implications.

5. Assess the impact navigation problems have on the mobility of elderly drivers.

6. Investigate the application of new route guidance technology as a means to reducing navigation problems.

1.4. Outline of the Thesis

The sequence of research presented in this thesis does not represent its chronological order. The experiment that is described in Chapter 8 occurred before the studies described in chapters 4 to 7. The outcome of the simulator experiment in Chapter 8 caused a shift in the thesis away from specific issues in the design of route guidance systems to more fundamental and exploratory non-experimental research. Issues about display design could not really be resolved without establishing navigational information needs. It was decided that more would be gained by focusing on the issues underlying navigation methods, navigation problems and the significance of these problems. The contents of each chapter are summarised below.

Ageing, driving and navigation are complex processes. Two chapters are dedicated to reviewing the literature on these topics. Chapter 2 discusses issues relating to the demographics of the ageing population, their travel trends and road safety. The changes in information processing as one ages and their implications for the driving performance of elderly people are also reviewed. The last part of Chapter 2 describes the potential implications wayfinding problems have for the mobility of elderly drivers.

The third chapter focuses on the navigation and wayfinding literature. The term wayfinding is defined and the importance of efficient and effective wayfinding is established. A theoretical model of driver wayfinding is proposed and theories on the causes of driver wayfinding problems are described. The different types and sources of route guidance information, and the environmental and individual factors such as ageing that affect wayfinding performance are identified.

Chapter 4 reports a preliminary investigation of issues in route navigation (Study 1). Focus group discussions were conducted with elderly and younger drivers and a questionnaire was given to the participants. Topics of discussion included wayfinding strategies and problems, and new route guidance technology.

Chapter 5 provides the rationale for the main empirical work of the thesis (Study 2). A postal questionnaire survey of drivers is described. Research methodology is reviewed and issues relevant to research on ageing are discussed. The second half of the chapter describes the survey methodology and content of the questionnaire. Details are given about the survey sampling, ethical considerations, survey procedure and analysis.

Chapter 6 presents results of the questionnaire survey of drivers. Results are discussed concerning respondents' characteristics and driving activities. Analyses look at both gender and age differences. Information on number and frequency of familiar and unfamiliar trips, situations that drivers avoid, and route planning and wayfinding strategies are described. Wayfinding information needs and problems in different driving situations are also identified. Lastly, the causes and implications of wayfinding problems are presented.

In Chapter 7, the results of the questionnaire survey of navigation and driving are discussed. The discussion examines these results in relation to the research literature and thesis aims. It first provides a description of respondents' driving activities and mobility. Route navigation strategies are then considered in relation to route planning and wayfinding. The wayfinding information needs of drivers are also discussed. The majority of this chapter deals with the epidemiology of wayfinding problems. The prevalence, types, causes and implications of these problems are examined. These problems are described according to the theoretical model of wayfinding presented in Chapter 3. Results concerning the influence individual (e.g., age) and environmental factors (e.g., road signs) have on wayfinding performance are also described. This is followed by an assessment of the impact wayfinding problems have on driving mobility. The chapter concludes with a discussion of some potential solutions to driver wayfinding problems.

Chapter 8 describes a study into the presentation of route guidance information (Study 3). A review of research indicates there has been no comparison of the effectiveness of route guidance displays using speech only or speech supplemented with visual information. A study was conducted in a driving simulator to investigate the safety and efficiency of presenting guidance information using a visual, auditory (speech) or a combined visual-auditory display. Recommendations, based on the results of this study and research literature, on how to present simple route guidance information are discussed.

Chapter 9 provides a summary of the thesis research. The thesis aims are re-examined in relation to the results of the focus group discussions, questionnaire survey and route guidance experiment. Contributions to knowledge and paths for future research are discussed. This last chapter ends with some final conclusions.

1.5. Chapter Conclusions

Route guidance systems have not been developed with sufficient consideration of driver needs. This is partly because little is known about what information drivers need to safely and effectively negotiate a path to their destination. There is also limited knowledge about the navigation problems drivers experience. These may have significant implications for road users, particularly the elderly. It is believed that they can threaten driver mobility and safety. In order to understand and address these problems, more information is needed about the navigation process and information needs of drivers.

This thesis aims to identify the navigation strategies people use and create a theoretical model to explain the process of driver wayfinding. It also aims to determine the types and causes of navigation problems and assess the impact these problems have on mobility.

Chapter 2: The Ageing Driver

2.1. Chapter Summary

This chapter is the first of two chapters reviewing literature relevant to navigation and ageing driver. It discusses the ageing of the driving population and the effects this has on driving behaviour, driving performance and mobility. The elderly driver is defined and issues of old age and driving are described. These issues relate to the demographics of the ageing population, their travel trends and road safety. Changes in information processing as one ages and their implications for the driving performance of elderly people are also reviewed. This is followed by an introduction to mobility and the factors contributing to driving mobility. Literature is also presented which indicates that elderly drivers experience problems wayfinding. Finally, this chapter describes the implications of wayfinding problems for the mobility of elderly drivers.

2.2. Introduction

There are many comprehensive reviews of elderly drivers in the literature which take a number of different foci. Some reviews emphasise the importance of accident risk (e.g., Schlag, 1993) and physiological changes (e.g., Smith, Meshkati, & Robertson, 1993), whereas others consider behavioural changes (e.g., Automobile Association, 1988; National Research Council, 1988; Planek & Overend, 1973a; Rosenbloom, 1993; Rothe, et al. 1990; Warnes, Fraser, & Rothengatter, 1992). This chapter presents some of the most current and relevant information on elderly drivers. The focus of this review is elderly drivers and not the ageing process in general. Where possible, research directly related to age and driving is presented. However in some cases, where research is lacking, data from more general psychological research is reported.

2.3. Definition of the Elderly Driver

Assigning an age to demarcate elderly drivers as a distinct group is difficult. This is because chronological age as a marker of development and performance is imprecise (Schroots & Birren, 1990). Physical and psychological ageing occur at different rates; therefore the impact age has on driving performance varies widely. There is not one homogenous group of elderly adults who can be identified simply by their living beyond a set chronological point. There appears to be three groups of older adults whose needs vary: middle-age people still employed, retired old people, and the frail, very old adults trying to maintain their independence (Charness, 1993).

Where possible in the present study, age is treated as a continuous variable to avoid problems of imposing unnatural classifications. Since classification is sometimes necessary for comparative purposes, an age by which to demarcate elderly drivers has been selected. Researchers have used ages 50 (e.g., Wierwille, 1990), 55 (e.g., Sixsmith, 1990), 60 (e.g., Barham et al., 1993); and 65 (e.g., Carr et al., 1992) to identify the population of elderly drivers. Planek (1981) described the age of 55 as being the general point at which the ageing process begins to degrade driving performance. If age only begins to influence driving after 55 years then its effects will be difficult to detect around this age. This research will use the age of 60 to identify the lower limit to the population of elderly drivers. This criterion includes employed elderly people who may drive more than those who are retired. This should help avoid confusion in differences that might be attributed to retirement rather than ageing.

2.4. Issues of Old Age and Driving

There has been an escalation in the amount of interest in elderly drivers. This interest has been prompted by factors such as population and travel trends. The following sections describe the importance of considering elderly drivers in transport research.

2.4.1. *Demographics*

The number of elderly drivers is increasing and there is concern about the implications this has for road safety and mobility. Several factors are contributing to this increase. The age distribution of the population in most western countries is shifting toward a greater number of elderly people. For example, in the United Kingdom in 1992, 21% of the population were over 60 years of age (OPEC, 1994). The population projection for 2020 has 25% of people being over 60 years of age (OPEC, 1994).

There has been a concurrent increase in the proportion of drivers amongst this elderly population. For example in 1976, 36% of people between 60 and 70 years of age held full car driving licences (DoT, 1993). Fifteen years later in 1991, the Department of Transport statistics indicated 54% of people between 60 and 70 years of age held driving licences. Hence there has been an increase, and there will be a projected increase, in the number of elderly driving licence holders.

2.4.2. *Driving Behaviour and Travel Trends*

With increasing age, drivers change their pattern of vehicle use. From cross-sectional survey data in the United States between 1977-83, Rosenbloom (1988) found elderly people drive significantly fewer miles than non-elderly drivers. They travel less than half as many miles as the average for all age groups (NRC, 1988). Drivers in the U.K. exhibit a similar decline in mileage with age. Elderly males drive less than half the mileage of their younger counterparts and elderly females drive a fifth as much as younger females (DoT, 1994) This reduction is attributed to an absence in work related mileage, an increasing proportion of women (who drive less) in the population of elderly drivers , and the recognition of decreased driving skills (Bly, 1993; Rosenbloom, 1988). However, Rosenbloom (1988) reports that individual trips, though shorter in length, are not appreciably different in number from those of drivers of other ages. They make more trips than younger drivers for non-work activities, shopping and medical visits, and fewer trips for social and visiting reasons.

Travel trends of elderly drivers are changing as well their demographics. With the increase in number of elderly drivers, there has been a concomitant increase in the amount of driving elderly people do. Although current elderly people drive less than non-elderly people, the gap in amount of driving between age groups is decreasing because of generational differences in car use and car dependency. "..those born in the 1930's and later have been the first cohorts to experience majority car ownership from early adulthood and to bring driving skills and habitual dependence upon cars into old age" (Warnes, 1992, p. 14). The extent of this dependence on cars is greatest in the United States where over 80% of all trips by people over 65 were taken in a car (FHA, 1992). Similar patterns are observed in the U.K. where the private car is the dominant mode of transport (Bly, 1993; DoT, 1996).

This dependence on cars has caused people to make a number of residential and lifestyle decisions which are practically irreversible (Rosenbloom, 1993). The growth of car travel encouraged and influenced migration to suburban settings and the development of new industrial and office estates, shopping centres and leisure centres in out-of-town locations (Bly, 1993). In these settings people have made decisions about doctors, hospitals, friends, and social and leisure options based on their lifelong access to the car (Rosenbloom, 1993) . Cars provide "...mobility, sociality, economic gain, existential meaning, and social status" (Rothe et al., 1990, p. 159). Jette and Branch (1992) reported in a longitudinal study that elderly drivers depend on car travel for as long as possible and, although they tend to reduce their frequency of driving, they resist any change to this preferred mode of travel.

Given this extreme dependence on cars, anything reducing access to them would interfere with elderly peoples' independence and lifestyle. It has even been argued that problems associated with reduced mobility in old age exceed the problem of reduced safety (Barr, 1991; Evans, 1994). Although driving may be a riskier activity for elderly drivers, the perceived risks may appear less threatening than a loss of mobility. However, it is more likely their safety and mobility are intrinsically linked and need to be considered together. Factors which influence the mobility of elderly drivers are discussed in more detail at the end of this chapter. Literature concerning the safety of elderly drivers is discussed in the next section.

Changes occurring to cars and the environment in which they are driven may also have an impact on the ageing driver. "Over the last thirty to fifty years, automotive and traffic engineering has changed considerably, as did the volumes of traffic, laws, and moral attitudes of society" (Rothe, et al., 1990, p. 138). Car and road speeds are increasing and traffic density is getting higher (DoT, 1996). These changes could make driving more demanding now than it was 30 or more years ago. Consequently, elderly drivers may experience more difficulties on today's roads.

The introduction of new technology will change driving. Intelligent transport systems (ITS) involve the use of advanced sensor, computer communication, and control technologies for traffic management, automation of vehicle control and driver information (Hancock, Dewing, & Parasuraman, 1993). In-vehicle systems such as collision avoidance, autonomous cruise control, vision enhancement, and route guidance will have a significant impact on the driving task. There is concern that these technologies will overload drivers by increasing the amount of information that has to be identified, perceived, and responded to (Stamatiadis, 1993). Elderly drivers may be more susceptible to overload from these systems than other drivers. Alternatively, these systems could help reduce the demands of driving for elderly people. For example, intelligent parking aids could make parking easier by displaying information (e.g., distance to a curb) which may be more difficult to obtain with a less flexible range of shoulder and neck movement.

These trends towards greater dependence on cars, increases in the amount of driving, more demanding driving conditions and the availability of new technology raises questions about the effects an ageing driving population will have on future road safety. This is of particular concern for collision risk because elderly people constitute a vulnerable component of the driving population.

2.4.3. *Road Safety*

Collision Risk

This section presents an overview of elderly drivers' safety risk. There has been much concern and debate about the safety risk of elderly drivers because they represent a high-risk component of the driving population (Waller, 1991). Research on collision risk indicates elderly drivers are less likely to be involved in a crash than the average driver (NRC, 1988). However, for North American and European drivers, there is an age related increase in risk of collision when you consider exposure; that is, the risk in relation to distance travelled or time spent driving (Evans, 1994). Therefore, elderly drivers have a lower number of collisions in relation to other age groups because they drive less. Consequently, with a trend towards having more elderly drivers who drive more often, on more demanding roads, one would expect the collision rate of elderly drivers to increase.

Age is one of several time-related effects which can influence driver performance. "In addition to aging, other important effects include driver cohort, driver attitudes and behaviour, and changes in the driving environment" (Stamatiadis & Deacon, 1995, p. 444) . Stamatiadis and Deacon, from a data base identifying at fault drivers over an 11 year period in Michigan, found "...middle age drivers are safer than younger drivers who, in turn, are safer than elderly drivers", p. 443. Driver cohort had an effect on time-related accident trends indicating elderly drivers in the future will be safer. Thus, future elderly drivers are safer as younger drivers than the previous cohorts of younger drivers. This difference is probably caused by their having acquired driving skills and attitudes which are more suitable to an automobile dominated society (Stamatiadis & Deacon, 1995). However, this cohort effect was small in comparison to the effects of ageing. Consequently, although future elderly drivers should be safer, they will still represent a greater risk than their younger counterparts.

Another road safety concern about elderly drivers is their physical vulnerability. The risk of being injured or killed in a collision increases with old age because their ageing bodies are more susceptible to injury. The consequences of these injuries also tend to be longer lasting because they recover more slowly than younger drivers (Evans, 1988).

Collision Patterns

With old age, and the increased risk of collision, there is also a change in the patterns of collisions. Collisions of elderly drivers frequently involve right-of-way violations, improper turns and lane changes, backing and parking, and ignoring signs and traffic lights (McKnight, 1988).

Hakamies-Blomqvist (1993) studied fatal collisions of elderly drivers in Sweden through a large number of multi-disciplinary crash investigation reports. The most typical collision for elderly drivers was at an intersection where they did not see the other vehicle or did not see it in time to avoid it. Other research has reported similar findings. Planek and Overend (1973a) reported that elderly drivers tend to have collisions while failing to yield, turning, and changing lanes. They are also more likely to make inattentive responses involving errors of omission, such as missing a traffic sign. Alternatively, elderly drivers are less likely to have collisions attributed to bad judgement, like driving too fast or following too closely. They are more often involved in two-car, as opposed to single vehicle collisions, and they have more day time crashes (Planek, 1981). This higher number of daytime collisions is probably due to their driving more during daylight hours.

Another pattern among elderly drivers is they tend to be held responsible for the collisions in which they are involved. North American and European statistics indicate elderly drivers are more often classified by police as being at fault than younger drivers (Hakamies-Blomqvist, 1993; NRC, 1988; Rothe et al., 1990; Schlag, 1993). Collision statistics cited in the preceding paragraphs would suggest this does not reflect a differential bias in reporting.

It is unlikely that cohort differences contribute to the different types of collisions elderly and non-elderly drivers have. This difference in collisions has been observed for some forty years. For example, McFarland, Tune, and Welford (1964) observed similar trends in California accident reports during the 1950's. If age cohort affected the type of vehicle collisions, a variation over time across cohort groups would be expected. A variation does not seem to occur or, if it does occur, it is very small as noted in research by Stamatiadis and Deacon (1995).

Certain age-related deficits in performance could give elderly drivers a greater risk of collision. This risk could be the consequence of problems with general and selective attention, judgement of speed and distance, field dependency, visual search, and visual field (McKnight, 1988). The following section describes relationships between age and driving performance in general. Although age has a diverse impact on people, focus will be restricted to changes relevant to driving performance.

2.4.4. *Ageing and Driving Performance*

Ageing process

While ageing is a universal phenomenon, it is not uniform across or within different physiological and behavioural systems (Fozard, Metter, Brant, Pearson, & Baker, 1992). Many different external (e.g., infectious diseases or environmental hazards) and internal factors (e.g., genetics) influence the ageing process. Consequently, the occurrence, rate and onset of age-related change varies between individuals. This causes the population of elderly adults to be very diverse, or more dissimilar than younger generations (Small, 1987). For the following review of ageing and driving performance, focus will be restricted to normal or healthy ageing. A discussion of the impact of external disease processes such as dementia (Kaszniak, Keyl, & Albert, 1991) or cataracts (Klien, 1991) on driving will not be included. Such conditions are likely to be better solved with medical treatment and not Human Factors Psychology.

It is difficult to isolate the influence that ageing has on driving performance. Drivers gain experience and advanced skill with age, yet they may also be affected by changes that can impede performance. The psychological and physical abilities that change with age, and changes in traffic environments, can all have an effect on driving performance. The following sections discuss age related changes in information processing and their implications for driving performance.

Driving Task

The task of driving has been divided into several different conceptual levels. Parkes (1991) has suggested that one of the móre useful descriptions of driving task elements is the three level hierarchical model employed by Janssen (1979). Janssen and others (e.g., Michon, 1985) have made distinctions between the strategic, manoeuvring and control levels of driving, see Figure 2.1. The strategic level involves activities like route planning. The manoeuvring level consists of conscious actions like passing or lane changing. The lowest level is control which includes automatic or reflexive driving actions like gear shifting and turn indicating. These control actions tend to take less time to complete than the higher levels tasks.

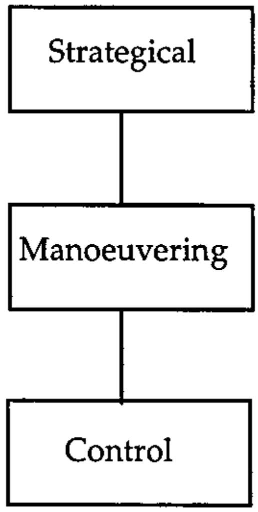


Figure 2.1. Hierarchical elements of the driving task.

The three levels of this hierarchical driving task model are linked to Rasmussen's (1987) knowledge, rule and skill-based model of behaviour (Michon, 1989; Rumar, 1990). *Skill-based* functioning involves the highly integrated and automatic performance of tasks without conscious control (e.g., gear change). With *rule-based* functioning, tasks are performed following learned conditional rules of action (e.g., lane change). *Knowledge-based* functioning depends on a conscious analysis of the situation (e.g., route plan). Familiar driving control tasks are formed at the skill-based level. For experienced drivers, many of the manoeuvring tasks may also be skill-based. Strategical driving tasks would be predominantly knowledge-based.

Information Processing

Certain aspects of information input and processing exhibit an age related decline. A basic description of how performance changes with age is that it generally slows down (Swearer & Kane, 1996). Although slower information processing should have some significant implications for driving performance, few convincing age differences have been found within the specific components of driving behaviour. For example, simple brake response times (e.g., time between first sighting an obstacle and release of the accelerator) do not differ significantly between elderly and younger drivers (Olson & Sivak, 1986), However, it is believed important age differences should appear with more complex driving activities (Smith et al., 1993) like driving in heavy traffic while reading road signs. Evidence from laboratory research supports this conclusion. On dual tracking tasks, performance has been found to decrease with age and task complexity (Korteling, 1993).

Planek (1981) summarises differences in driving behaviour observed between elderly and non-elderly drivers. Generally, elderly people drive more slowly and are poorer at judging gaps, maintaining lane position, controlling speed and reversing.

Figure 2.2 is a qualitative model of human information processing that has been adapted from (Wickens, 1990). The critical stages of information processing are described in this model. It will be used as a framework for discussing changes which occur in old age and how they affect general performance and driving.

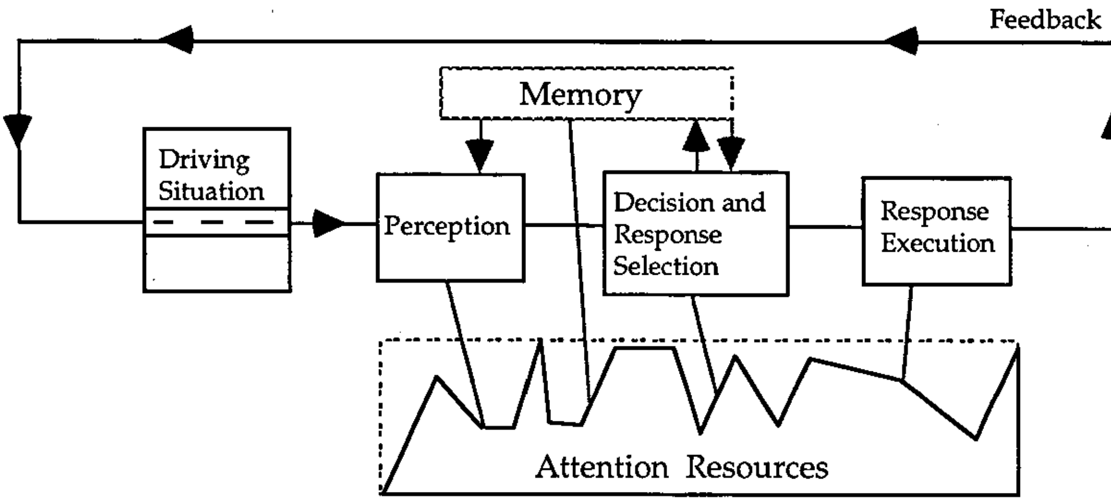


Figure 2.2. Theoretical model of information processing adapted from Wickens (1990).

Perception

Age has an impact on all sensory processes. These changes can influence the quality and quantity of information obtained and the subsequent stages of information processing (Wickens, 1990). Senses most essential for driving are vision and hearing to a lesser degree.

The perceptual change most relevant to driving performance is the decline in visual function. Vision is a very important component of driving because it is the main source of information for operating a car safely and effectively (Wierwille, Antin, Dingus, & Hulse, 1988; Lansdown & Fowkes, 1995). Vision is the most commonly recognised sense associated with normal ageing (Small, 1987) and all dimensions of visual function decline with age (Shinar & Schieber, 1991; Smith et al., 1993). These changes can begin at physical maturity (middle teenage years) but impairment does not become significant until later in life. Kline and Fuchs (1993) and Owsley and Ball (1993) review the physiological causes of age-related declines in vision. Corso (1992) and Fozard (1990) summarise some of the general research on visual changes occurring with age. Kosnik et al. (1988) identified five dimensions of visual function that create difficulties for elderly people in their daily lives. These are: reduced visual processing speed, light sensitivity, dynamic vision, near vision, and visual search. All of these five dimensions have implications for driving performance.

A decline in visual processing speed would create special difficulties for driving because it involves rapidly occurring visual events (Owsley & Ball, 1993). For example, with this decline, elderly drivers need more time to read information on road signs or in-vehicle displays.

A reduction in light sensitivity makes it more difficult to see at twilight or in darkness. It has been reported that elderly drivers could only read signs at night at 65% of the distance of young drivers (Chrysler, Danielson, & Kirby, 1996; Shinar & Schieber, 1991). Thus at night, elderly drivers can see things at less distance than non-elderly drivers. Elderly drivers require more time to adjust to sudden changes in light levels (Owsley & Ball, 1993). Glare on windscreens or from headlights at night is a serious problem for elderly drivers and can degrade driving performance (Shinar & Schieber, 1991).

As dynamic visual acuity deteriorates, drivers have more trouble reading signs while their vehicle moving. A positive relationship between poor dynamic visual acuity and accident involvement among elderly drivers has also been reported (Shinar & Schieber, 1991).

Decline in near vision (hypermetropia) creates a variety of problems for elderly drivers. A reduction in near visual acuity reduces their ability to read small print like on a map or instrument panel. A decline is also present in far visual acuity (myopia) and contrast sensitivity. As a consequence, there is a significant reduction with age in the distance at which highway signs can be read (Evans & Ginsburg, 1985; Kline & Fuchs, 1993).

Visual search difficulties would reduce drivers' ability to detect other road users and signs or landmarks. Some dimensions of visual search which exhibit a decline with age are movement detection (Scialfa, Kline, & Lyman, 1987), reduction in field of view, peripheral vision, and speed of initiating eye movements (Dewar, 1988). There is also a decline in some higher levels of visual functioning such as the ability to ignore irrelevant information (Owsley et al., 1991). These will be described later in this chapter in the review of the cognitive aspects of ageing.

Schieber et al. (1992) conducted a survey of visual difficulties experienced by elderly drivers. They identified the following five concerns: unexpected vehicles in the periphery of visual field, difficulty judging vehicle speeds, dimly lit instrument panels, windshield glare, and inability to read street signs.

Although important, hearing is not as essential to driving as vision. Hearing thresholds and discrimination decline significantly with age (Fozard, 1990). This loss in hearing reduces feedback from engine sounds and acoustic warnings and displays. Driving relevant communication with passengers may also be hampered. External noises such as warnings from other cars and emergency vehicles are also important to driving. Hearing impairment can be exacerbated by ambient noise inside cars which has an additional masking effect similar to hearing loss (NRC, 1988). Ambient noise levels are a particular concern for elderly people. They have more trouble hearing in noisy environments because the ability to distinguish between signal and noise declines with age (Fozard, 1990).

Decision and Response Selection

After a stimulus has been perceived, drivers need to decide how to respond. For familiar situations, they rely on decision rules; as with the skill-based or rule-based levels of functioning. These automatic decisions and responses would be quick and require minimal processing and attention. However, for novel situations, drivers require more time and attentional resources. Such decisions require them to search their memory or seek out additional information. This decision and response selection process exhibits a number of age related changes. They can be manifested in the attentional resources, memory and rate of decision making.

All stages of information processing require attention for them to function effectively. Attention is a limited resource that shifts across processing stages supervising their activity (Wickens, 1990; see Figure 2.2). Automatic skill-based processing tasks require minimal attention where as knowledge-based tasks require greater amounts of attention (Rasmussen, 1987).

Attention, irrespective of sensory processes, is related to safe driving performance (Kahneman, Ben-Ishai, & Lotan, 1973). Age-related deficits can be found in divided attention, attention switching, sustained attention, and selective attention (Czigler, 1996; McDowd & Birren, 1990) Divided attention refers to the process by which attention is controlled to successfully perform two simultaneous tasks. Maintaining lateral and longitudinal position while trying to obtain navigational information requires divided attention. Attention switching refers to the alternating of monitoring between stimuli. Driving requires the switching of attention among many sources of information like the instrument panel and road environment (Wierwille, 1990). Sustained attention is required for vigilance type tasks involving infrequent targets over a prolonged period of time (Parasuraman & Nestor, 1991). Sustained attention is important for good driving performance on prolonged journeys. Another attentional skill is selective attention which refers to the filtering out of irrelevant information and focusing on task relevant information (McDowd & Birren, 1990). The identification of relevant information from amongst irrelevant "noise" while driving is critical to performance. Among these various attentional skills affected by age, Parasuraman and Nestor (1991) identify attention switching as being the most highly related to accident risk among drivers. This is because safe driving requires the coordination of attention to several tasks together.

Memory supplies information to support decisions and response selection or it can be used to store information about decisions (Wickens, 1990). It tends to be conceptually separated into at least two different levels:

working memory and long term memory. These represent different depths of processing and are not unitary constructs (Hultsch & Dixon, 1990). Working memory is a limited capacity store used for the temporary storage, selection and manipulation of information. Long term memory stores facts about meaningful materials, tasks, activities and events.

Experimental ageing research has identified that advanced age is generally associated with impaired memory function (Nyberg et al., 1996). Although total knowledge increases with age, there is a decrease in the ability to acquisition or retrieve information stored in long term memory (Hultsch & Dixon, 1990). Furthermore, the rate of memory search declines significantly with age in maturity and elderly people have slightly smaller working memory capacities than non-elderly people. There is no specific research on the relationship between age and memory in the context the driving. Consequently, it is uncertain whether these changes in memory would have a noticeable impact on driving performance.

In addition to memory and attention, there are also age changes to the rate of decision making in old age. A decrease in the rate of decision making in old age has been consistently and reliably demonstrated in the adult development literature (Cerella, 1990). This decrease would slow the decision and response selection stage of information processing. Although the research has not been conducted to show this in driving, it would seem reasonable to expect a similar slowing in performance.

Response Execution

Execution of a response follows the decision to generate a response. Success of response execution depends on physical timing, force, precision and appropriate movements. These physical features of response execution show a decline with age. For example, simple reaction time, the time from stimulus presentation to response completion, increases in old age. This is because adults initiate and execute movements more slowly and with less precision as they age (Stelmach & Nahom, 1992).

Physical changes occuring with age also have an impact on driving performance. Smith et al. (1993) describe these physical changes. In general, there are progressive decreases in body height, sitting height and eye height (Stoudt, 1981). There is also a reduction in the range of motion at various joints and viable extremes of body position (Small, 1987). With respect to strength and force, elderly people are weaker and can exert less force (Smith et al., 1993). However, as with many aspects of ageing, there is a wide variation between individuals and muscle groups.

The main physical challenge for elderly drivers is vehicle entry, exit and seating (Smith, et al., 1993). Physical changes also restrict visibility outside the vehicle. Specifically, decreases in seating height and range of motion in the upper body and neck reduce elderly drivers' ability to scan around the vehicle (Isler, Parsonson, & Hansson, 1996; Smith, et al., 1993; Yanik, 1988). Less flexibility has been shown to relate to actual driving performance among elderly people (McPherson, Ostrow, Michael, & Shaffron, 1988).

The impact these physical changes have on driving performance will depend on vehicle design. Certain features in the design of cars can make driving easier for elderly people (Yanik, 1988). For example, automatic transmission and power steering benefit elderly drivers because they demand less physical effort than non-assistive systems. Also, difficulty with visual scanning would be accommodated by better designed seat adjustments, mirrors, head restraints and roof pillars (Smith et al., 1993). Consequently, it is important to consider vehicle design when assessing the performance of elderly drivers because results might be attributable to unsuitable vehicle design rather than ageing effects.

Exceptions to Age Related Declines in Performance

Up to this point, age has only been described with reference to decline. The review may be perceived as being overly pessimistic. This has been an intentional emphasis in order to outline the range and potential for problems the population of elderly drivers may experience. It should be emphasised here however, that ageing does not have a uniformly negative impact on driving and mobility. Factors such as practice, predictability of responses, and physical fitness also influence the extent to which age affects performance (Spirduso & MacRae, 1990). Also, age does not exclusively mean decline among all facets of individuals. Changes in information processing are varied. Some functions decline with old age (e.g., vision), some show no significant change (e.g., sense of humour), while others improve (e.g., knowledge). Furthermore, decline that does occur may not be sufficient to influence driving behaviour.

From a more positive perspective, people accumulate knowledge and skills with age. As a result, this learning might counteract many age-related declines in driving performance. Years of practice may compensate for any loss of cognitive skills caused by ageing; perhaps because some components of a task become automated (Morrow, 1996) or they develop compensatory strategies to accomplish tasks. These strategies may offset declining resources by streamlining task components (Morrow, 1996). Alternatively there is accommodation, where the strategy is to change the task itself (Salthouse, 1990). Consequently, some changes in driving performance which may have been attributed to a decline in information processing may actually be the result of strategic or attitudinal changes (Rothe et al., 1990).

2.4.5. Changes in Personality and Attitudes

Personality is another psychological feature of drivers that is often examined in an attempt to explain and predict behaviour. Much of this research focuses on the contextual risk-taking personality styles of young male drivers (e.g., Burns & Wilde, 1995; Furnham & Saipe, 1993; McMillen, Smith & Wells-Parker, 1989). Elderly drivers are not generally considered to be high risk-takers. They tend to be responsible drivers who will admit reduced abilities and use strategies to avoid risks (Planek & Overend, 1973b; Rothe et al., 1990; Warnes et al., 1992). The words *cautious* and *slow* are commonly used to describe elderly drivers.

Another aspect of elderly drivers is they seem to have less confidence relative to their younger counterparts and find driving more stressful (Rothe et al., 1990). In speculation, their level of confidence may reflect a realistic appraisal of their driving ability. However, elderly drivers may only lack confidence in comparison to younger drivers who over-estimate their skill and carry an unrealistically high level of confidence.

2.5. Driving Mobility

Elderly people tend to compensate for age related declines in driving performance by changing the patterns of their driving behaviour. For example, a large proportion of elderly drivers avoid driving at night or on unlit roads because they have poorer night vision and experience problems with headlight glare (AA, 1988). The most commonly avoided situations are night driving, rush hours, turning across traffic, city centres, motorways, long trips, bad weather and unfamiliar routes or areas (AA, 1988; Carp, 1971; MTO, 1994; Rabbitt et al., 1996; Rothe et al., 1990; Simms, 1993; Yee, 1985) Having to avoid any of these driving situations poses significant restrictions on mobility.

Driving cessation is the ultimate restriction to mobility. The anticipation of giving up driving is considered to be very negative (Carp, 1971). This is particularly problematic for elderly drivers who have non-drivers depending on them for their transportation (Rosenbloom, 1993). Marottoli et al. (1993) investigated driving cessation in a longitudinal study of 1,331 elderly American drivers (65+ years). The predictors of driving cessation from their logistic regression analysis were: higher age, lower income, not working, neurological disease, cataracts, lower physical activity, and disability.

Driving a car is the most common method of travelling for elderly people in the United States (FHA, 1992), Canada (MTO, 1994; Rothe et al., 1990) and United Kingdom (DoT, 1994). "For people who cannot drive, transportation problems may severely limit all aspects of life during the retirement leisure years" (Carp, 1971, p. 184).

The term mobility has several dimensions. It can refer to the amount of travelling people do in terms of distance or frequency. It can also mean people's ability to travel (Robson, 1982) or their freedom of movement. Rosenbloom (1988) describes mobility as "The ability to move about at will, to engage in social and recreational activities when desired, and to reach business and social services when needed", p. 21.

There is an important link between the concept of mobility and accessibility. Accessibility, according to Robson (1982), describes how easy it is to get to a place. Places are less accessible to people in cars if driving to them is considered difficult. The accessibility of a place decreases as features like the distance, time, cost, effort or stress involved in travelling there increase. Mobility makes places more accessible.

These definitions indicate mobility can be a very subjective or objective phenomenon. For the purposes of this research, the definition of mobility will be the ability to travel independently and conveniently.

2.5.1. *Mobility and Well-Being*

Mobility is a major contributor to the well-being of elderly people (Carp, 1988). People's well-being is dependent on fulfilment of their needs and mobility contributes to well-being by assisting people to fulfil these needs. Individual appraisals of mobility are positively correlated with global measures of well-being (Andrews & Withey, 1976). This relationship is supported by views of the elderly, research on housing location and the importance of having access to services and facilities (Carp, 1988). Figure 2.3 is a conceptual model describing the relationship between mobility and well-being of the elderly, adapted from Carp (1988).

The qualities of mobility that help people to achieve their needs are its feasibility, safety, and personal control. The *feasibility* for driving mobility would be the individual's ability to travel by car. *Safety* is the amount of risk associated with car travel relative to the alternatives. *Personal control* describes the individual's ability to use a car independently and at their own convenience. These qualities of mobility are affected by an individual's socioeconomic status, situation and technology. The cost of driving may restrict its availability to some *socioeconomic* groups. *Situations* such as night or unfamiliar routes also restrict driving mobility. Carp (1988) suggests *technology* will moderate the qualities of mobility by accommodating travellers' needs. She gives the example of how the technology of powered steering could assist elderly drivers with limited upper body strength.

The dimensions of psychological well-being listed in Figure 2.3 are: *self-esteem, usefulness, happiness, loneliness, anxiety* and *depression*. Well-being depends on the satisfaction of certain higher-order needs like the ability to socialise. It is also linked, through independent living, to satisfaction of life maintenance needs such as food and clothing. Mobility is essential to the congruence between a person's needs and the accessibility of resources to meet these needs (Carp, 1988).

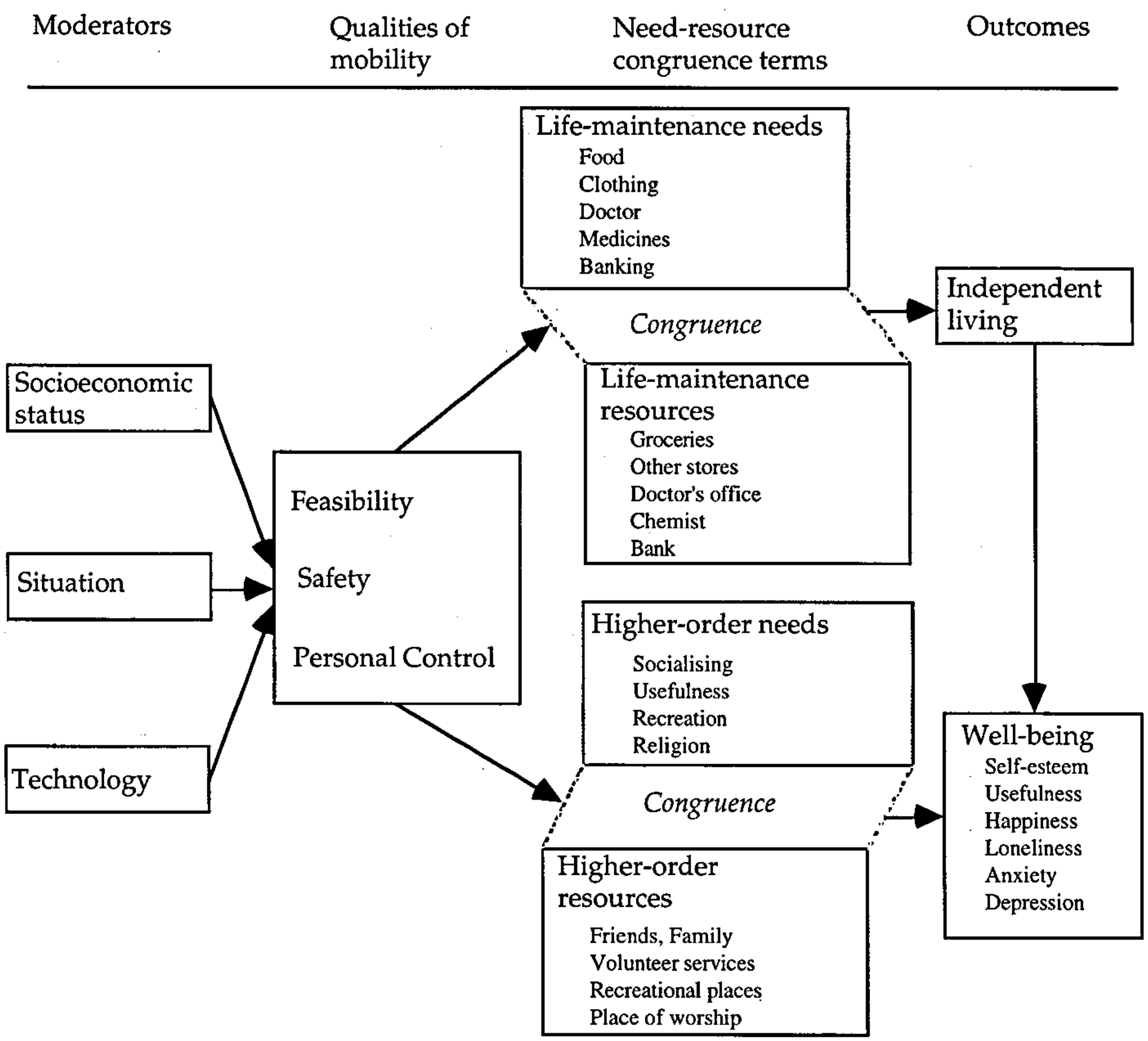


Figure 2.3. Relationship between mobility and well-being, adapted from Carp (1988).

Carp's (1988) model can be used to explain how driver wayfinding problems would have a disruptive impact on mobility and well-being. The ability to travel to unfamiliar places is a feature of mobility afforded by driving. The three qualities of mobility (feasibility, safety and personal control) facilitating a driver's ability to meet their needs would be diminished by wayfinding problems. Driving would be less feasible for people who have trouble finding unfamiliar destinations. For example, it would be impractical to drive to a new restaurant if you could not find your way.

Wayfinding problems may also detract from the safety of driving. Rothe et al. (1990), from interviews on the collision experiences of elderly drivers, reported it was relatively common for victims to have been searching for certain streets, road signs, house numbers, or business establishments when collisions occurred. Furthermore, being in unfamiliar neighbourhoods, rushing to find shortcuts or searching for anticipated but unknown motorways or side streets were major distraction factors leading to collisions.

Personal control, the third quality of mobility listed in Carp's (1988) model, could also be affected by wayfinding problems. Drivers may be forced to rely on the assistance of others to find their way. This would eliminate some of the independence and convenience afforded by cars.

The impact wayfinding problems have on elderly drivers' mobility is difficult to isolate because there are many other factors associated with old age which also have a negative impact on mobility. The three moderators described in Carp's (1988) model (socioeconomic status, situation and technology) would also influence the ability to travel to unfamiliar places. Furthermore, there is a range of other factors which influence mobility beyond those described by Carp. The impact technology, situation and socioeconomic status and additional factors have on mobility is described in the section below.

2.5.2. *Influences on Mobility*

Economic Status

The financial cost of car ownership and use is a barrier to mobility (NRC, 1988). Costs of running a car become more significant with reductions in income after retirement. According to Carp's (1971) survey, economic status was the most important factor in determining whether retired people drove. It also had a large influence on the destination and frequency of their trips, and their ability to meet needs through driving.

Rabbitt et al.'s (1996) research on driving cessation found financial resources to be one of the main categories of reasons for giving up driving.

Similarly, Marottoli et al. (1993) found decreased income is associated with driving cessation.

Situation and Location

The ability to drive in different situations is a feature of mobility. Driving is not always feasible or safe in certain situations. The main situational factors restricting driver mobility were described earlier. They were night-time, rush hours, turning across traffic, city centres, motorways, long trips, bad weather and unfamiliar routes or areas.

The amount of driving people do and their need to drive varies depending on the location where they reside. Elderly drivers living in rural areas drive greater distances and more frequently than drivers living in cities (Gelau, Metker, & Traenkle, 1992). This is because public transport tends to be inadequate and distances between resources are much greater in rural areas (Everitt & Gfelliner, 1997). Furthermore, there are fewer home services (e.g., meals on wheels) available to rural residents.

Access to cars is also essential in suburban settings. It has been reported that people could not live in suburbs without a car (e.g., Carp, 1971; Rosenbloom, 1988). It is suggested that this is because suburbs have been developed around car travel.

People who live in cities drive less because public transport tends to be better in cities and distances between resources (e.g., shops) are often shorter (Carp, 1971). Furthermore, driving is more demanding in cities where there are higher levels of traffic and the road network is more complex. Consequently, drivers may be less inclined to use their car to travel in cities because there are better transportation alternatives. Additional problems such as parking costs and availability in cities may also be a deterrent to travelling by car.

Technology

Technology can contribute to mobility only if it is suited to the needs of the elderly driver. It can make driving more or less accessible. As mentioned earlier in this chapter, certain features in the design of cars can make driving easier for elderly people (Yanik, 1988). The example was automatic transmissions benefit elderly drivers because they demand less physical effort than manual gears.

New intelligent transport systems represent another means by which technology can enhance or detract from elderly drivers' mobility. For example, route guidance technology may provide elderly drivers with the assistance and confidence necessary for travelling on unfamiliar trips (e.g., Oxley & Mitchell, 1995). Alternatively, technology could represent a hazard to elderly drivers if they impose excessive demands on the driving task (e.g., Stamatiadis, 1993). For example, traffic congestion warning devices that display complex information to drivers about travel conditions might require a large amount of attention to read. The benefits of appropriately presented in-vehicle information are discussed further in Chapter 8. Another concern is that technology may de-skill drivers. For example, automatic cruise control systems, which maintain a set speed and distance between vehicles, could de-skill drivers by removing control of some of the driving tasks.

Access to Cars and Alternative Transportation

The availability of a car has an obvious impact on mobility; "Absence of an automobile for available use tends to be reflected in a low mobility rate, rather than in use of a different form of transportation, and in dissatisfaction with the ability to get about" (Carp, 1971, p. 183) Furthermore, if a person owns a car they tend to use it for every transportation need. However, having someone else to drive you or a preference for public transportation are factors which have been found to contribute to driving cessation (Rabbitt et al., 1996).

Employment

Employment is another factor that influences mobility and has been shown to predict driving cessation (Marottoli et al., 1993). The retired and unemployed drive less than the employed. "Retirement may affect both the need to drive and the income to afford to drive" (Marottoli et al., 1993, p. 259). The decline in the need to drive occurs because retired people no longer have to commute to work or engage in work–related travel. This reduction in need to travel does not influence mobility because mobility is linked to the fulfilment of needs. However, a decline in income after retirement does reduce mobility. Unemployment would also be expected to have a similar negative impact on mobility. It is uncertain whether employment has an affect beyond the economic ones discussed earlier.

Health

Health and fitness are also strong predictors of mobility. Drivers who consider themselves to be in poor health restrict their driving frequency and distances they drive (AA, 1988; Carp, 1971; Marottoli, et al., 1993; Rabbitt, et al., 1996; Schlag, 1993). Poor health is also a reason for giving up driving. For example, elderly people who give up driving report more visual problems than their counterparts who continue to drive (Kosnik, Sekuler, & Kline, 1990).

Drivers' health problems can affect both their ability to drive and their safety. Feeling unsafe as a driver was one of the main reasons for giving up driving reported in Rabbitt et al.'s (1996) study. Nevertheless, concerns about the safety of driving may not always cause drivers to restrict their driving or stop it completely. Drivers may be forced to continue driving beyond the point at which they feel able to drive safely because cars are essential to mobility in our society (Bly, 1993).

Activity Level

Activity level, which is dependent on health, also predicts driving mobility. Marottoli et al. (1993) found decreased physical activity (e.g., being able to walk one-half mile or climb a flight of stairs) was the only factor, other than increasing age, that could distinguish between whether or not drivers had decreased their mileage in the previous five years. However, they pointed out it was uncertain whether inactivity preceded or was followed by a reduction in mobility. This is an important consideration because it has also been suggested there may be a reduction in the desire to travel that can occur before any losses in the ability to drive (Rosenbloom, 1988). This may also explain another way in which employment can influence mobility. Employed individuals, as a consequence of higher activity levels, are more mobile.

Personal and Household Characteristics

Mobility is also influenced by household composition. The presence of dependants or other drivers in one's home can affect mobility. Driving might increase if dependent family members need to be driven. Alternatively, having a spouse or children who can drive would reduce a person's need to drive. One reason for giving up driving is the availability of another driver (Rabbitt et al., 1996) . There may also be family pressure on an elderly person to drive less because of their concerns for safety.

The impact gender has on mobility is inconclusive. Carp (1971) found women were more likely to place restrictions on their driving than male drivers. However, Marottoli et al. (1993) found gender to be unrelated to driving cessation or a reduction in mileage. Nevertheless, gender could be indirectly related to mobility through income and employment.

There are certainly other demographic factors which would have an impact on driver mobility (e.g., ethnicity and education). However, it is believed they influence mobility indirectly through factors already described above. For example, education would affect the ability to afford the costs of driving as it is strongly linked to employment and income.

2.6. Wayfinding Problems and Mobility

This thesis is primarily concerned with the wayfinding problems of elderly drivers (See Chapter 3 for a discussion of wayfinding). It is also interested in the extent to which these problems affect mobility. Wayfinding difficulties were the most widely mentioned of three main problem areas identified in discussion groups with elderly drivers (Sixsmith, 1990). The two other main problem areas were night driving and declining abilities. The combination of busy, fast roads and poor sign posting is sufficient to make the experience of wayfinding so difficult it would deter elderly drivers from travelling on unfamiliar journeys (Sixsmith, 1990).

Elderly drivers appear to compensate for problems in wayfinding by avoiding unfamiliar routes. Pauzie and Letisserand (1992) reported in a survey of French drivers (N = 764, with 100 respondents over 65 years of age) that 49% of people over 65 years avoid driving on unfamiliar trips (they do not mention the percentage of younger drivers). Also, the Automobile Association's Foundation for Road Safety Research (1988), based on an interview survey of 996 U.K. motorists over 55 years of age, reported that elderly drivers tend to avoid long or unfamiliar journeys as they age and prefer to drive in familiar areas. Rabbitt et al. (1996) found from a questionnaire survey that 47% of U.K. drivers over 55 years of age

(N = 2134) had reduced the amount of driving they do in unfamiliar areas during their previous three years.

Having to avoid unfamiliar routes imposes a serious restriction on mobility and lifestyle. Being constrained to familiar routes prevents a driver from travelling to any new places. This would result in a very limited range of movement and a restriction of vacation travel by car. Furthermore, there is evidence that memory for routes declines in old age (e.g., Rabbitt et al., 1996). Consequently, the range of familiar routes may be even less for elderly drivers.

As outlined in the previous section, there are many factors which influence mobility in general. These same factors would affect mobility on unfamiliar routes. For example, changes in lifestyle associated with retirement and old age could cause a reduction in the number of unfamiliar trips driven by elderly people. As they drive less than younger people, it is also likely they travel on fewer unfamiliar routes. Alternatively, because elderly drivers have more experience, they would be more familiar with the road network. Consequently, they may have fewer unfamiliar route options simply because their knowledge of the roads is more extensive than the less experienced younger drivers.

It is clear many factors contribute to a reduction in the number of unfamiliar journeys elderly drivers undertake. However, it is believed wayfinding problems represent a significant deterrent to going on unfamiliar trips. One of the aims of this research is to determine the extent to which wayfinding problems impact drivers' mobility. Figure 2.4 displays the wayfinding problems and other factors which can interfere with people's ability to travel independently and conveniently between places. Wayfinding problems in the situation and location moderator might be caused by the darkness of night or the complexity of a city. Wayfinding performance could also moderate mobility through technology (e.g., route guidance systems), health/fitness (e.g., vision), activity levels (e.g., driving experience) and demographics (e.g., gender and age). These factors are inter-related in their influence on mobility and will all have to be considered in order to assess the impact of wayfinding problems.

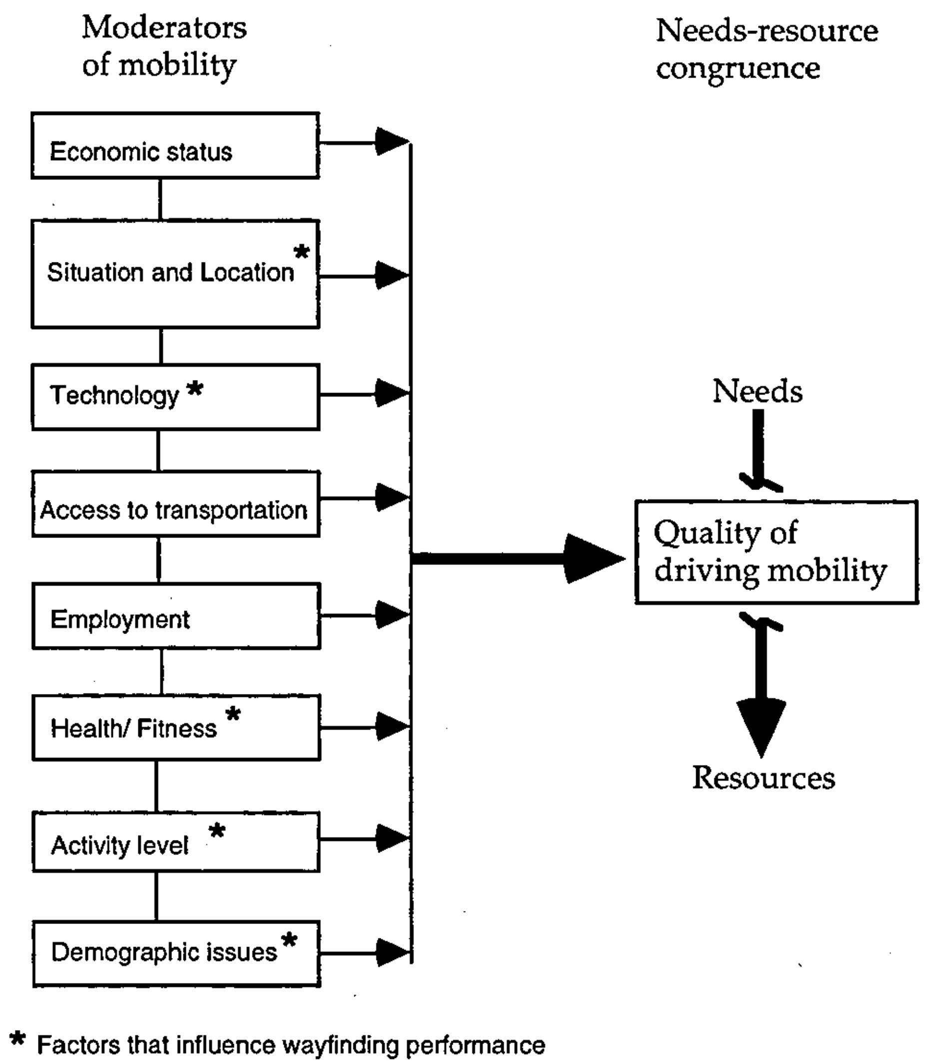


Figure 2.4. Factors predicted to affect the mobility of elderly drivers.

2.7. Chapter Conclusions

This chapter reviewed the literature on elderly drivers and ageing. It described how there is concern about the increasing population of elderly drivers because they may be less safe than non-elderly drivers. This increased safety risk is attributed to ageing. There is a significant behavioural slowing that occurs with age in maturity and a decline in visual function. As a consequence of these changes, elderly people drive slower and have more trouble judging gaps, maintaining lane position and reversing. They also have problems with night driving, city centres and unfamiliar routes. Elderly drivers tend to cope with these difficult situations by avoiding them. This avoidance may have a negative impact on their mobility which is a concern because mobility is associated with people's well-being and independence. It is argued that the navigation problems of elderly drivers reduce their mobility. This remains to be investigated. The next chapter discusses driver wayfinding theory and research.

Chapter 3: Route Navigation

3.1. Chapter Summary

This chapter discusses the literature on route navigation. The term wayfinding is defined and the importance of safe and efficient wayfinding is highlighted. A theoretical model of wayfinding, based on fundamental theories in the literature, is proposed to explain the process in a driving context. Different types and sources of route guidance information, and the environmental and individual factors which affect wayfinding performance are identified. Of particular focus among the individual performance factors are those which may be susceptible to ageing. Theories on the causes of route navigation problems are also described.

3.2. Introduction

> *"... he had a tremendous propensity for getting lost when driving. This was largely because of his 'Zen' method of navigation, which was simply to find any car that looked as if it knew where it was going and follow it. The results were more often surprising than successful, but he felt it was worth it for the few occasions when it was both."* (Adams, 1988, p. 46).

The research literature does not discuss being lost and how we get *unlost* explicitly (Gluck, 1991). There is also a surprising lack of knowledge about what information people generally need to find their way, and what factors affect these information needs (Gluck, 1991; Mark & Frank, 1991). This is particularly true for the specific field of transportation research which has largely neglected the process of wayfinding. This neglect is startling considering that wayfinding is a fundamental component of driving.

Wayfinding is important when one considers that the principal purpose of driving, in most cases, is to safely, conveniently and independently get from one point to another. Difficulty in finding your intended destination decreases the utility of this form of transportation and threatens the mobility of its users.

Wayfinding problems could have severe implications considering that the car is the most common means of personal mobility (FHA, 1992).

Wayfinding errors also have implications for road safety. Driving is not a particularly demanding task in most instances (Näätänen & Summala, 1976). However, navigating a car on unfamiliar roads can be very demanding on a driver's attentional resources (Wierwille et al., 1988). Rothe et al. (1990), from interviews on the collision experiences of elderly drivers, reported that it was relatively common for the victims to have been searching for certain streets, road signs, or addresses when the collision occurred. Furthermore, being in strange areas or searching for anticipated but unknown roads were major distractions that led to collisions. Mourant, Rockwell, and Rackoff (1970) found that the visual demand of roadway information is higher on unfamiliar routes. Gurgold and Harden (1978) argue that a poor ability to follow and retain directions could create unsafe driving.

In addition to these affects on mobility and road safety, wayfinding problems can lead to wasted time and fuel, and contribute to traffic congestion. Navigational waste is considered to be a significant problem by transport researchers. Navigational waste or excess travel "... is the difference between the amount of travel that actually occurs on the network and the amount that would occur if every vehicle trip followed the desired optimum route" (Bovy & Stern, 1990, p. 265). Estimates have been made that four percent of travel in the U.K. is navigational waste (Jeffery, 1981). Wayfinding problems are also likely to be stressful and embarrassing to drivers. However, little is known about the causes and implications of these problems. In order to determine why elderly drivers avoid unfamiliar routes and why they have problems finding their way in unfamiliar environments, it is important to review what is known about how people find their way in cars.

3.3. Driver Wayfinding Research

Minimal research has been done to identify the strategies drivers use to plan their routes and find their way to unfamiliar destinations. Road maps appear to be the most common form of navigational assistance for drivers. Sheppard and Adams (1971) conducted a random survey of British male drivers (N = 128) to assess their opinions on the use of maps for route finding. Respondents were asked if they would use a map to plan a trip of over 50 miles on unfamiliar roads. They reported that 95% of drivers in their survey would use a map to plan their route. Forty-four percent of respondents said they would use a map during the trip if they were driving alone.

Astley (1969), in an earlier study of 300 British motorists at a service station, found almost half of the respondents relied on written notes to navigate. The majority of these notes were taken from maps. Unfortunately, Astley's survey consisted mainly of professional drivers and his findings may not apply to all motorists. Furthermore, both of these studies were conducted over 25 years ago and navigation strategies may have changed in that time.

Mark and McGranaghan (1988) conducted a more recent pair of studies to investigate route navigation strategies in an American urban setting. They found 87% of respondents (N = 48) would refer to a map when travelling in an unfamiliar city. Maps tend to be used more for planning than for in-transit navigation. They compared the use of verbal procedural directions to maps. Unfortunately no statistical conclusions could be drawn because of limitations in their experimental design (Mark & McGranaghan, 1988).

Streff and Wallace (1993) investigated drivers' preferences for travel information. They conducted a postal survey of members of a motoring organisation in Michigan (N = 2764). Respondents indicated a clear preference for directions from maps supported with written information and/or verbal instructions from a passenger when driving in an unfamiliar area. The three most common complaints about maps were that they did not provide enough detail, were poorly designed (e.g., size and folding), or were out of date. However, the majority (78%) of respondents found maps easy to use.

Although Streff and Wallace (1993) surveyed a large sample of drivers and the results have some intuitive appeal, their survey only skimmed the surface of route navigation. They only asked about wayfinding in *familiar* and *unfamiliar areas*. These terms are imprecise considering that *areas* could be urban, suburban or rural and this, as well as the road type (i.e., motorway or country lane), may have an important influence on the strategies people employ. Also, their 30.7% survey response rate from a select population may not provide an accurate indicator of peoples' driving behaviour. Similarly, strategies of drivers in America may be different to those in the U.K. (Mark & McGranaghan, 1988). Motorists in the U.K. may adopt different strategies for wayfinding because the urban road environment here, and in most of Europe, is considerably less predictable than the grid patterns found in North American towns and cities.

A few studies have also looked at informational aspects of wayfinding. Gordon and Wood (1970) had two groups of 10 young American drivers travel to two different unfamiliar destinations (an address in another town) using whatever information they could obtain. A control group of five drivers were given directions from an experimenter. The unfamiliar drivers drove less efficient routes in terms of time and distance. Most of their time was lost in the vicinity of their destination. Almost all of them would travel to the local area then consult a service station attendant for specific directions. "Local wayfinding is difficult because the driver must obtain detailed information that is not available on large scale maps", p. 46.

Another relevant study on driver wayfinding was conducted by Schraagen (1990). He had a sample of 24 drivers report concurrent verbal protocols while they tried to find their way through an unfamiliar Dutch city. There were five categories of information identified from the verbal protocols of drivers' navigating and Kuipers' (1978) theory on the acquisition of spatial information (see page 39). They were street names, road signs, landmarks, topographical knowledge (e.g., road characteristics, road types, counting streets), and metric knowledge (e.g., distance, compass orientations, angles). Of these categories, the drivers were suggested to mainly attend to street names, landmarks, and road signs for navigation.

Obata, Daimon, and Kawashima (1993) also conducted verbal protocol analysis on the navigational information needs of five male students driving in Japan. The participants were unfamiliar with the route. No details were reported about the type of area the route was through. Drivers mostly requested information about landmarks to identify their next decision point (e.g., traffic signals, shops and signs) and the distance to that point. The generalisability of these finding is questionable because of the small and non-representative sample studied.

Upon review of this literature it can be said that there is only a superficial knowledge about what people use to plan their routes and find their way while driving. Consensus from research described above would suggest people mainly use maps and take notes in preparing to drive to an unfamiliar destination. While driving alone they follow their notes or memory of a map. Previous research does not address many of the issues which are relevant to this thesis. For instance, what information do people need to find their way in a city, or outside a city, and do older people need different information? There is a need to examine the concept of wayfinding more closely.

3.4. Defining Wayfinding and Navigation

Wayfinding has been given many different definitions beyond the literal *finding a way*. These definitions can be associated with abilities or procedures. Blades (1991) defines it as the ability to learn and remember routes through an environment. Cutting et al. (1992) define wayfinding as "... the ability to find one's way through and around objects in a cluttered environment", p. 42. Wayfinding has also referred to how well people are able to find their way to a particular destination without delay or undue anxiety (Peponis, Zimring, & Choi, 1990). Rovine and Weisman (1989) say it is the ability to identify one's location and find desired destinations in the environment. Passini (1984) describes wayfinding as a person's cognitive or behavioural ability to reach spatial destinations. Gluck (1991) describes wayfinding as the process humans use to orient and navigate on foot or by vehicle in order to accurately relocate from one place to another in a large-scale space. Golledge (1992) defines wayfinding as procedures for searching the environment to find a path that can link an origin and a destination.

Wayfinding can also describe how spatial knowledge is acquired, the ability people have to find their way, or the process they use to find their way. The variety of definitions reflect the disparate aspects of wayfinding that have been investigated. "Clear sets of well-authenticated criteria for explaining wayfinding do not exist" (Golledge, 1992, p. 210).

This thesis is interested in how people find their way while driving and the problems they encounter while doing this. It is not particularly concerned with how people learn about their environment. Thus, for the purposes of this research, wayfinding will refer to the dynamic step-by-step decision making process that is required to negotiate a path to a destination (Golledge, 1992; Passini, 1984). This does not include route planning.

The terms navigation and wayfinding are often used synonymously. Although they can both represent spatial problem solving activities (Kitchin, 1994), there are subtle differences. Navigation is a broader term that refers to both the strategic route planning level of the spatial problem solving task and wayfinding, whereas wayfinding involves the actual movement and execution of these plans.

3.5. Theories of the Wayfinding Process

The two main movements within wayfinding research are the generally theoretical *competence* literature and the more empirical *performance* literature (Gluck, 1991). The competence literature focuses on cognitive models of the processes involved in wayfinding. These models tend to be based on either computational or information processing theory. This section discusses models of wayfinding by Kuipers (1978), Passini (1984), Gärling, Böök, and Lindberg (1984), and Chown, Kaplan, and Kortenkamp (1995). Although there are other theories of the processes involved in wayfinding (e.g., Freundschuh, 1991; Leiser & Zilbershatz, 1989), the essential concepts will be sufficiently covered in a review of these four theories.

The performance literature examines peoples' abilities to find their way (see sections 3.6 and 3.7). The performance and competence literature are somewhat overlapping. However, for the sake of clarity, their discussion herein will be separate.

3.5.1. Computational Models of Wayfinding

Kuipers' (1978) model of spatial learning is a computational model of how people acquire environmental information through wayfinding. According to Kuipers, as people move through space they observe *views* and perform *actions*. The view is what is seen from a specific orientation at a specific place. An action is the movement that changes a particular view. A learned route involves a proceduralised set of these view-action pairs. In Kuipers model, as people become more familiar with the environment, their knowledge progresses from declarative and procedural route knowledge to a more topographical and metrical representation of space.

There are a number of limitations to Kuipers' theory. Thorndyke and Hayes-Roth (1982) suggest that procedural knowledge of a route contains more information than these view-action pairs. There is additional information about distance travelled along route segments, the angle of turns, and features of the terrain along the route. It is believed the process described by these computational models is different from how people actually learn about and find their way within an environment (Golledge, 1992).

3.5.2. *Information Processing Models of Wayfinding*

Passini (1984) describes wayfinding in buildings as a spatial problem solving activity. Successful wayfinding depends on decision making, decision execution and information processing. Travellers must make decisions at each point along a route where they are faced with more than one option. For example, at a crossroads a driver has four possible manoeuvres to choose from, they could: continue straight on, turn left, turn right or stop (turning around would involve these other manoeuvres). Information for the decisions is obtained from the traveller's spatial representation of the environment. Some of this environmental information "...may be perceived directly in the setting, some retrieved from previous experience or inferred from a combination of existing information" (Passini, 1984, p. 154).

After the decision is made it must be executed. This process of transforming a decision into action requires the traveller to match a selected behaviour to an object or place specification (Passini, 1984). For example, turn left (action) at the Bull's Head pub (place specification). Environmental information is used to specify an object or place for the response.

As with Kuipers (1978), a series of successive wayfinding decisions lead to linearly and temporally organised route type spatial representations (Passini, 1984). The organisation principles of an environment leads to survey-like representations. For example, knowing the orientation and structure of the major arteries through a city provides a foundation to build a configurational representation of that space. When specific routes become more familiar, this process of executing decision plans becomes more automatic and requires little attention. Drivers travelling to work after years of commuting along the same route do not need to consider their different options at every decision point because the rehearsed action has become almost reflexive.

Another information processing theory of wayfinding has been proposed by Gärling et al. (1984). Their model extends beyond the basic wayfinding process and models the formation and execution of travel plans, see Figure 3.1.

Stage 1 in Figure 3.1 is the action plan. People form action plans to achieve a goal or fulfil some need. For example, a person might need to have their hair cut and the action plan would be the decision to go to a barber. The travel plan in Stage 2 of Gärling et al.'s (1984) model is connected to this action plan. The goal of travel plans is to reach a desired destination (i.e., the barber's shop). Travel plans involve decisions about the specific destination, mode of travel and route to take. Information about the environment is needed to form and execute this plan. Place information can consist of a name, affective characteristics, perceptual characteristics, function and spatial scale (Gärling et al., 1984). Information about how to get there and where it is located is available from media like maps and verbal directions. This information can also be obtained from a cognitive map if the place is familiar. These media are described in more detail later in this chapter in the section on route information.

Wayfinding occurs at Stage 3 of Gärling et al.'s (1984) model. The execution of the travel plan is wayfinding. Information that supports wayfinding here is perceived directly from the environment or from the traveller's cognitive map. The process of executing travel plans helps to build a cognitive map by acquiring new environmental information. While executing travel plans, travellers monitor their progress. "Recognizing places, keeping track of one's location when moving about, and anticipating features in the environment are important means through which monitoring is accomplished" (Gärling, et al., 1984, p. 26). In an unfamiliar environment, the wayfinding task is likely to dominate the traveller's attentional resources. Route familiarity tends to make the execution process more automatic and people no longer need to monitor every step of their progress.

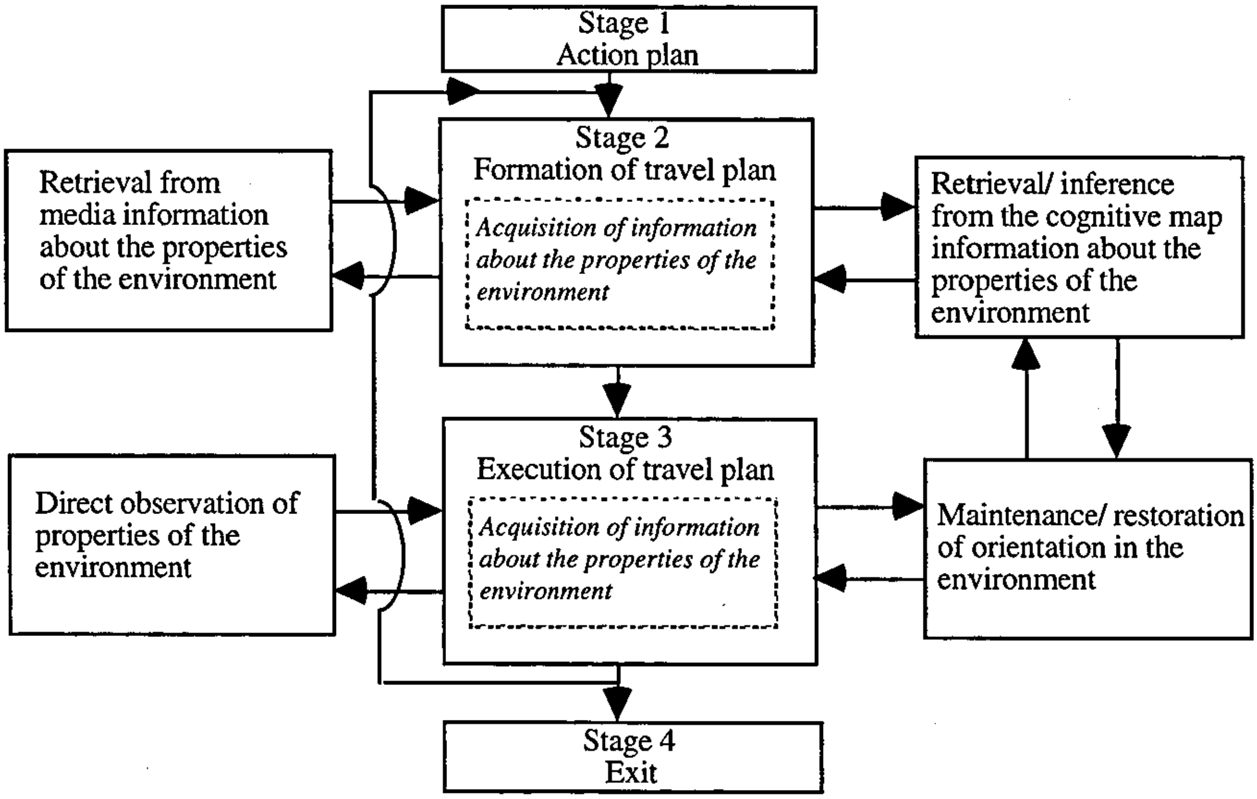


Figure 3.1. Model of the formation and execution of travel plans adapted from Gärling et al. (1984).

Chown et al. (1995) developed a theory of cognitive mapping that also explains the wayfinding process. They suggest that there are four sub-tasks to wayfinding: landmark identification, path selection, direction selection, and *creating abstract environmental overviews* (i.e., cognitive mapping). Landmark identification is considered the most basic component of wayfinding. The recognition of a landmark helps people to locate themselves in a familiar environment. Path selection is the choice of route to a destination. They describe a path as "...a series of places that lead to a goal" p. 2. It does not involve a direction. The third wayfinding task is direction selection and it involves the choice of direction or orientation in which to travel. The fourth task is the abstraction of route overviews which is the generation of a mental representation of the route environment. According to Chown et al. (1995), the first three tasks must be accomplished for successful wayfinding. The fourth task, cognitive mapping, serves to enhance the efficiency and functionality of wayfinding.

3.5.3. *A Model of Driver Wayfinding*

Theoretical descriptions of wayfinding in the driving context have been proposed. The task of driving a car can be divided in three elements: navigation, manoeuvring and control (McRue et al., 1977). This is equivalent to the hierarchical model proposed by Janssen (1979) in Figure 2.1. The navigation task has been defined simply as spatial problem solving (Alm, 1993). The purpose of this task is to get from a starting point to a particular destination. This involves navigation decisions at each node or intersection in the roadway network (Antin, 1993). These decisions can be planned in advance or made while driving. Drivers need certain information to make these navigation decisions. Most importantly, drivers need to know which direction to drive, when to turn, and which way to turn. They also need to know about how far they are from their destination, when they have arrived, and their progress (feedback from their manoeuvres). This requires the recall of a cognitive representation of the desired route or the extraction of this information from a printed map, road environment, human navigator, road signs, written instructions or an electronic navigation system (Schlegel, 1993).

Prabhu et al. (1996) have outlined similar elements of the driver wayfinding task. They theorise that it requires the "... localisation of the present position and destination on the map, internal representation of the environment, a relationship between the map and the world, relative judgements about movement and distance estimation" p. 884.

These descriptions of the driver's wayfinding task are very basic and do not outline all of its elements. A more detailed theoretical model is needed for the purposes of this research. Figure 3.2 is the information processing model of Wickens (1990) described in Chapter 1 adapted herein to consider the wayfinding theories proposed by Passini (1984), Gärling et al. (1984), and Chown et al. (1995). According to this model, when drivers encounter a decision point they must resolve the uncertainty of having more than one path option. Information which reduces the uncertainty of wayfinding decisions must be recognised from our perception of the environment or be obtained from the traveller's cognitive map stored in memory. This environmental information is used to assess the situation. In this assessment the drivers consider their progress, orientation and path options. Once they have assessed the environmental information, they then attempt to select the most appropriate path and direction in order to travel to their intended destination. After the decision is made drivers must execute it at the decision point. This process is repeated whenever the driver encounters uncertainty about their progress along a route.

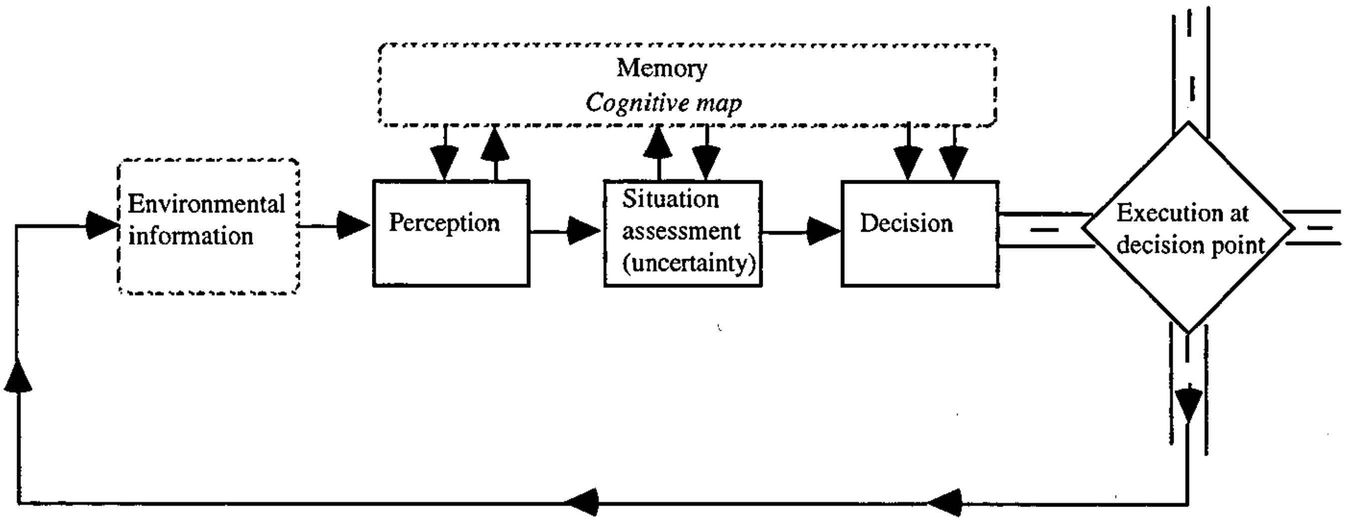


Figure 3.2. Theoretical model of driver wayfinding.

3.5.4. *Environmental Information*

Travellers can rely on a variety of different types and sources of information to support their wayfinding decisions. For example, Schraagen (1993) identified five categories of environmental information that drivers use to find their way: street names, road signs, landmarks, topographical knowledge (e.g., road characteristics, road types, counting streets), and metric knowledge (e.g., distance, compass orientations, angles). This section describes different sources of environmental information and identifies the types of information they may provide. However, because the medium may be linked to the message, the distinction between information source and type is not always obvious. This particularly applies to our cognitive representations of environmental information.

Types of Spatial Information

Spatial information can vary in its *globalness*. It ranges from *local* references like landmarks to *global* references such as points on the compass or global latitude and longitude co-ordinates (Golledge, 1992; Lawton, 1996). An example of a global reference would be *the pub is north of here*, whereas a local reference would be *the pub is in the next village*. A global reference is Euclidean where as a local reference would tend to be non-Euclidean. The spatial knowledge contained in cognitive maps is best described by non-Euclidean metrics (Medyckyj-Scott & Blades, 1990).

Spatial Knowledge

Spatial knowledge is acquired through our experience within an environment. There is a general consensus in the literature that there are at least two kinds of spatial knowledge (e.g., Evans, 1980; Freundschuh, 1989; Golledge, 1987; Hirtle & Hudson, 1991; Thorndyke & Hayes-Roth, 1982). The first type is route knowledge which is essentially the knowledge of sequential locations without knowledge of general interrelationships. The second type of spatial knowledge is configurational or survey knowledge. This is a mental two dimensional map-like representation of space that includes measures such as angles and distances. Geographers have distinguished between more forms of spatial knowledge (e.g., Freundschuh, 1991; Gluck, 1991) but they can generally be encompassed within these two categories.

Route learning usually involves the grouping or chunking of route segments (Golledge, 1992). Grouping route information makes it easier to learn and organise the large amount of information that makes up a route. It also helps in the recall of the route.

Both declarative and procedural knowledge are required for wayfinding tasks (Gale et al., 1990). Declarative knowledge is the ability to describe features of a route, while procedural knowledge is the ability to follow the route. People may know certain facts about a route and not have the ability to negotiate that route

(Gale, et al., 1990). Gale et al. also found that route knowledge can be quite parsimonious. Wayfinding does not require extensive knowledge about all the scenes along a route; only the critical decision points. There is also a need to be involved in the wayfinding decisions in order to proceduralise the information.

There is a diversity in the strategies people use to acquire spatial knowledge (Anooshian, 1996). Blades (1991) emphasises the importance of strategy in learning new routes; "...a route can be learned as a series of landmarks, as a list of directions at choice points, as a series of street names, and so on..." p. 158. However, the most important features of a route to learn are the choice points (Gale, et al., 1990).

It has been theorised that spatial knowledge grows from an initial landmark and route type knowledge to the more detailed configurational knowledge (e.g., Kuipers, 1978). However, spatial knowledge does not necessarily progress from route knowledge to configurational knowledge; "...some knowledge of configuration can develop independently rather than by somehow aggregating the knowledge of specific routes..." (Peponis, et al., 1990, p. 576) . A person can learn the configuration of a space from a map or similar representation without having physically travelled through the space (Thorndyke & Hayes-Roth, 1982). "We may also travel through an environment by reading a book, by listening to a verbal description, or by viewing image records such as slides, tape, or television transmission." (Golledge, 1992, p. 200). Nevertheless, most environmental information is acquired by travelling though it (Gale, et al., 1990; Golledge, 1992) and this knowledge tends to become more accurate with increased experience of the environment (Thorndyke & Hayes-Roth, 1982).

Cognitive Maps

The composite of spatial knowledge is represented as a *cognitive map*. Cognitive maps are a source of information concerning spatial relations and environmental attributive data which allows us to operate within an environment and process environmental and geographical data (Kitchin, 1994). They are developed from our experience with an environment (e.g., through navigational experience, maps and verbal descriptions) and contain a complex array of spatial information such as location, orientation, distance and density. The fundamental purpose of cognitive maps is wayfinding (Chown, et al., 1995).

Spatial schemata are a feature of cognitive maps which contribute to their development and use. Medyckyj-Scott & Blades (1992) define a schema as "...a framework or outline of essential information which is necessary to define a specific concept" (p. 219). Blades (1991) suggests spatial schemata provide us with a general understanding of the layout and pattern of typical environments (e.g., a city) and contribute to effective wayfinding in these environments. "Few adults are ever in the situation where they cannot make assumptions about a new area from their general knowledge of other environments" (Blades, 1991, p. 152). "The more you have travelled to other cities, the more you acquire general knowledge of the way cities are organised" (Beck & Wood, 1976, p. 208). New information that is encountered is added to the existing schema in the cognitive map (Devlin & Bernstein, 1995). Examples of spatial schemata that would assist in wayfinding include: the knowledge that slip roads are used to exit or enter motorways, and rivers are generally traversed using bridges or tunnels.

Evans (1980) suggests cognitive maps function as schemata on at least two levels. These levels have been referred to as global and instantiated schemata (Dillon, 1994; Brewer & Treyens, 1981). A global schema is the basic or raw knowledge structure which is highly general and does not reflect any specific spatial information. Instantiated schema are created by adding specific new details gained from our direct experience with an environment to our global schema (Dillon, 1994). While instantiated schemata are developed from our experience with a specific environment, global schemata are abstracted from the common features taken from our experience with several geographically different but similar environments. For example, a driver travelling in an unfamiliar area needs to reach a destination on the other side of the river. From his experience of similar situations in the past (global schema), he expects there to be a bridge. He looks for a bridge and does not find one. He eventually finds out the only way to get across is by ferry. The knowledge of how to cross the river in this place is added to his cognitive map of the area (instantiated schema). The general fact that sometimes rivers can be crossed by ferries is added to his global schema.

Landmarks

Landmarks are point references (Lynch, 1960) or known places (Golledge, 1992) that provide location information. They can be used to "anchor directions or to act as foci for wayfinding or the regionalizing of information" (Golledge, 1992, p. 200). Landmarks can be particularly helpful in the absence of a grid pathway structure (Evans et al., 1984) or other such predictable environments. Features like buildings, trees, junctions and parks can be landmarks. The characteristics of landmarks are important because they influence their ease of recognition. Among others, these characteristics are location, name or identity, colour, shape and size (Golledge, 1992).

In Schraagen's (1990) study of navigation in unfamiliar cities, the majority of drivers (57%, N = 24) preferred to have clear landmarks when receiving directions. Other studies have also identified the importance of landmark information for driver wayfinding (Akamatsu, Yoshioka, Imacho, & Kawashima, 1994; Alm, 1990; Burnett, May, & Ross, 1994).

Path Segments

Paths, the channels on which travellers move, tend to be the predominant element in peoples' image of cities (Lynch, 1960). The paths for drivers are roads. Street names and road types are critical to wayfinding because they help the traveller to identify the paths which link them to their destination. Path information, road characteristics (e.g., A-road) and street names, are some of the main types of information used by drivers navigating in unfamiliar cities (Schraagen, 1990).

Decision Points

Nodes, or decision points, are another prominent feature of peoples' cognitive maps identified by Lynch (1960). These choice points are the intersection between paths. In order to stay on route while wayfinding, drivers need information about the appropriate path choice at each decision point. There are many different types of decision points in the road network which vary in their complexity: for example, there are crossroads, T-junctions, forks in the road, roundabouts, lane changes and motorway merges. "Fewer decision points on any route to a destination will result in easier and quicker wayfinding" (Arthur & Passini, 1990, p. 6).

Orientation Information

Wickens (1990) describes three types of spatial information used in navigation: forward view, orientation, and position. Forward view refers to what drivers can see ahead at a given time; which is the same as Kuipers (1978) concept of *views*. Orientation is the bearing or direction of this forward view. Drivers might obtain orientation information from a compass, the sun or their own sense of direction. Position information represents the driver's physical location in space. Sources of position information can be internal or external. Internal position information may come from the driver's cognitive map. External position information is available from maps, landmarks, a route guidance system or passenger directions.

Wickens (1990) suggests that *spatial orientation* exists when there is a convergence of all three sources of environmental information (e.g., forward view, orientation and position). A *sense of being lost* or disorientation occurs when there is a lack of convergence. Although spatial orientation may assist wayfinding, it is not entirely necessary or sufficient for success. For example, some drivers could rely on information from their forward view to make a successful wayfinding decision (e.g., follow road signs). This may occur even when drivers have a sense of being lost.

The three spatial representations identified by Wickens (1990) describe static positioning. However, it is believed there are additional sources of spatial information used to develop a sense of orientation while wayfinding. Rate of movement through space is another source of information that may help support wayfinding decisions. An awareness of your rate of movement would help determine your progress along a route. This information could be provided by a speedometer, optic flow and/or the passage of time. Many drivers describe routes using temporal information (e.g., Smith Falls is an hour's drive outside Ottawa on the way to Kingston).

Sources of Wayfinding Information

This section discusses the sources of information that are available to assist drivers in wayfinding. Some of this information can be categorised as being from inside or outside the vehicle. For example, map information would come from inside the vehicle and road sign information would appear outside. However, these categories are not exclusive and some information can be available in both places. Compass orientation information could be displayed by a compass inside the vehicle or from clues in the environment like the position of the sun or the orientation of features like churches. Rate of movement information could also come from an in-vehicle source like a speedometer or from the speed at which outside objects move through one's visual field.

Information Outside the Vehicle

Roadside signs can provide drivers with all the information that is necessary for wayfinding. Route guidance signs can be distinguished from other types of signs by their size, shape, placement and colour (Lajunen, Hakkarainen, & Summala, 1996). For example, according to the European traffic sign system, route guidance signs are rectangular, warning signs are triangular and prohibitive signs are circular. Signs provide spatial information about location, path segments (road and street names), direction, distance, layout (e.g., an overview of a complex junction), and the interrelations between places (e.g., ordered list of towns or landmarks).

In-Vehicle Information

Maps provide people with many different types of environmental information. They give a configurational representation of the road network and the different categories of roads. They also display distances, directions and landmarks. McCann (1982) has identified 18 separate map tasks ranging from orientation to memorisation.

One problem with road maps is they tend to contain excessive information for a single journey. Consequently, it is difficult to extract information such as location and orientation quickly from the clutter of a map (Antin, 1993). Their size and design may also make them difficult to handle and dangerous to use while driving. The strength of maps is that they allow for error recovery and provide information about other possible destinations (Mark & McGranaghan, 1988). For example, if drivers go off their intended route a map can help them to find their way back on track. This is not the case with route notes.

Route notes are a common source of in-vehicle information for wayfinding (e.g., Astley, 1969). They can be derived from maps or information provided by a person who is familiar with the route. Route notes can also come from a computer route planning program (e.g., AutoRoute) or a motoring organisation (See Table 3.1). These notes, which are often customised by the individual traveller, can provide spatial information for routes (e.g., a list of decision points and landmarks) and configuration information (e.g., sketch maps of junctions). The advantage of notes is they operationalise the step-by-step decision making that is needed to negotiate a route. The problem with notes is they are useless if drivers goes off the planned route.

Table 3.1. Automobile Association Route Guidance Program © route plan for a trip to Sheffield from Loughborough.

Accumulated Miles	Distance Miles	Directions
		Loughborough, Leics.
		From Town Centre or Ring Road:
		Follow signs Derby A6
2.8	2.8	In 1.2 miles at roundabout forward
3.2	0.4	**Hathern ("Dew Drop Inn")**
5.9	2.7	**Junction with A6006/B5324**
6.9	1.0	**Kegworth (church)**
		Junction with A453/M1
		At roundabout take 4th exit
		(signposted The North) to join Motorway M1
15.8	8.9	**TROWELL SERVICE AREA**
43.2	27.4	**WOODALL SERVICE AREA**
		LITTLE CHEF RESTAURANT (237)
48.1	4.9	**Junction 32 (M18)**
		Take right-hand lane (signposted Sheffield, Leeds)
51.9	3.8	**Junction 33 (A630)**
		Leave Motorway (signposted Sheffield Centre)
		& at roundabout take 1st exit A630
55.0	3.1	**Junction for A6102 (Ring Road)**
		SHEFFIELD SERVICES
		Forward through underpass A57
		By Parkway enter
57.2	2.2	**SHEFFIELD**
		Section time 1:06, Total time 1:06

Another source of wayfinding information is passenger instructions. They are a preferred method of wayfinding (Streff & Wallace, 1993). Passengers can provide drivers with the information necessary to make wayfinding decisions or s/he can make decisions for the driver. Passengers may obtain the same information as the driver (e.g., from a cognitive map, road atlas, route notes, etc.) and can convey this information verbally or by pointing.

The advantage of having a passenger navigating is that drivers have fewer tasks to perform. Passengers could also devote all their attentional resources to the task whereas drivers need to maintain some of their attention on driving. Problems may arise in communicating between driver and navigator. The passenger may not supply the information that is needed, or at the time it is needed. Drivers however, interact with the passenger and can request information as required and can specify what they need. No research has been found that investigates this process.

In-vehicle route guidance systems are also a potential source of wayfinding information. "...Advances in microprocessor technology in terms of size and price reduction, power efficiency, durability, as well as similar advances in the associated display technologies have made new forms of onboard navigation aids feasible" (Antin, 1993, p. 321). Many different types of route guidance systems have been, or are being developed. More than ten different systems were described in two recent technical publications (Dempsey, 1996; ITS, 1996).

In-vehicle route guidance systems are intended to make car travel more efficient, navigation easier, and driving safer (CEC, 1991). With their installation, the efficiency of travel could be improved through time savings, fuel savings and better use of the road infrastructure. Route planning functions and in-vehicle guidance displays could make wayfinding easier. The systems could also enhance driving safety by reducing demands on drivers.

These systems help drivers by providing a range of navigation relevant information. Route guidance is just one category of route information that can be provided by these in-vehicle systems. Route information has been subdivided into three categories: route planning, route navigation and route guidance (Ashby & Parkes, 1993). Route planning, which is done before a trip begins, might require information about route options, weather conditions, traffic patterns, and the availability of service facilities. With route navigation, drivers are given details about the road network and are left in control of route decisions. These systems typically provide an electronic moving map display, mounted on the vehicle's dashboard, that is updated as the vehicle moves along a route (e.g., TravTek; Andre, Hancock & Smith, 1993). The map displays the road network around the car with vehicle position and orientation indicated in the centre. The maps move relative to the vehicle with up on the map typically representing what is ahead.

Ashby and Parkes (1993) describe route guidance as being real-time in-transit route information that guides drivers with a set of procedural instructions through each manoeuvre to a destination. At a minimum, route guidance systems provide drivers with information on the distance and direction to a specified destination (Antin, 1993). These systems tend to guide manoeuvres with direction arrows and supplementary digitised speech instructions.

In-vehicle route guidance systems get their vehicle position information from different sources (Schraagen, 1993). Positioning information can come from satellites and road beacons. Vehicle position can also be determined from within the vehicle using dead-reckoning and map matching techniques. These monitor progress by comparing distance and direction information to a digitised map database. Some systems use a combination of techniques for greater accuracy (e.g., PathMaster).

Despite the many potential benefits of route guidance systems, there are also some serious limitations. As mentioned in Chapter 1, the most significant limitation is their impact on driving safety. Their introduction in cars may place more demands on drivers and interfere with safe operation of the vehicle. Indeed, research has shown that route guidance systems do distract drivers' visual attention away from the road ahead (e.g., Wierwille, 1993). The safety of these systems should be thoroughly assessed before they are employed. These issues are explored in more detail in Chapter 8.

3.6. Wayfinding Performance

The wayfinding performance literature examines peoples' abilities to find their way. The discussion here is about the causes and variations in wayfinding performance. Many factors which influence, or cause variations in, performance have been described in the research literature. These are covered in the second part of this section. Before that, different wayfinding problems and approaches to assessing wayfinding performance are reviewed.

3.6.1. *Wayfinding Problems and Errors*

The safe, efficient and successful completion of a journey represents good driver wayfinding performance. Experiencing navigational problems while negotiating a route to a destination would represent poor wayfinding performance. Wayfinding problems could involve making an error, getting lost, having to stop and ask for directions, and the stress or other affective implications caused by the uncertainty and insecurity associated with disorientation.

Research on driver wayfinding performance has identified a range of error types. Wickens (1990) and Andre (1991) have described how a *sense of being lost* or disorientation has a number of manifestations. Firstly, it is possible to know roughly, but not exactly where one is located. For example, a driver might know s/he is in London but not know the specific street corner. Then there is the condition of knowing where you are but not where to go (i.e., a lack of orientation). For example, a driver could know s/he is at Trafalgar Square but have no idea whether they are facing east or west. Alternatively, drivers can know the direction they are going but not their specific location (Andre, 1991). In this situation, the driver could be heading north on the motorway but have no idea what junction they are near. Being completely lost is the greatest degree of disorientation. Drivers are completely lost when they do not know where to go or where they are located.

Schraagen (1990) had a sample of 24 drivers give verbal protocols while they tried to find their way through an unfamiliar city. A navigational error in this study was a departure from the planned route. Although this is a vague definition, it is common in the research to simply state navigation errors. Other studies evaluating route guidance methods that use navigation errors as a dependent measure also fail to provide a description of this measure (e.g., Parkes, Fairclough, & Ross, 1991; Zaidel & Noy, 1994). In these cases the reader can only guess the departure from correct wayfinding. It is uncertain whether they are referring to errors like missing a turn, taking a wrong turn, going off the intended route, or getting completely lost.

Mark and McGranaghan (1988), in their two studies of wayfinding in cities, found that 16 of the 55 participating drivers made unintentional departures from their planned route. A description of the magnitude and cause of these *unintentional departures* was not provided. Nine drivers encountered uncertainty as to whether or not they were *on course* while driving to their destination. Three drivers stopped to ask for directions while *en route*.

Streeter, Vitello, and Wonsiewicz (1985) conducted a study comparing the effectiveness of route guidance aids on a sample of 57 drivers travelling through an unfamiliar suburban area. The performance measures used by Streeter et al. were time to complete the route, distance driven, number of turns, number of repeated instructions, number of referrals to the map, number and type of navigational errors. They identified eight different types of wayfinding errors which varied in their severity: unable to find location while searching; saw location while driving past; did not go far enough; thought on wrong street, but correct; turned in wrong direction; turned onto wrong road; missed location, but not aware of it; and never found correct road.

Wierwille et al. (1988), in a study evaluating an in-vehicle route guidance system, assessed navigational performance in relation to spatial ability, age, driving experience, traffic density, and road type. Navigational effectiveness was rated by an experimenter on a scale of 1 to 5; where 1 meant the subject got lost and 5 meant the subject had no problem finding the destination. Scores between 1 and 5 were given to drivers who reached their destination through indirect routes or committed errors. *Errors* were not specifically defined. Trip duration was also measured to assess navigational performance.

Walker, Alicandri, Sedney, and Roberts (1991) assessed a various methods of presenting route guidance information to drivers in a low fidelity simulated driving environment. They defined the errors relative to each decision point. The errors were turning in the wrong direction, turning before and driving beyond the correct intersection. The degraded simulator environment and experimental design were blamed for some of the navigation errors that were committed. However, these errors were not considered in their assessment of the performance of the different route guidance systems.

No research has been found that explored age differences and the types of route navigation errors that occur. The following section outlines factors that may cause wayfinding problems.

3.7. Factors Affecting Wayfinding Performance

Performance has been described in relation to a number of factors. Schraagen (1990) attributed navigational errors to three factors: errors due to insufficient map inspection, memory failures and insufficient visibility in the environment. Gould (1989) suggests that level of spatial knowledge, sense of direction or spatial ability, and individual differences in attention to or ability to attend to environmental cues are all important to wayfinding performance. Freundschuh (1991) describes three factors that influence the acquisition of spatial knowledge: arrangement of the environment, density of geographic information, and variation in individual spatial cognitive ability. These factors would have a similar impact on wayfinding performance. Blades (1991) considers children's wayfinding performance in terms of individual memory strategies, task strategies, encoding, metacognition, knowledge, and social mediation. Gärling, Book and Lindberg (1986) describe three environmental properties related to wayfinding performance: degree of differentiation of the environment, degree of visual access, and complexity of layout.

There are also local (i.e., specific) and global (i.e., general) environmental factors which influence wayfinding performance (Peponis et al., 1990). For wayfinding in buildings, the local causes of problems were identified as a lack of information sources like signage, marked entrances, or other directly perceived cues. The global causes relate to the complexity of a space which cannot be directly perceived while wayfinding. Liben (1981) proposed three major components that affect spatial activity (e.g., wayfinding) and representation (i.e., cognitive maps). These factors are individual characteristics, environmental characteristics and cultural heritage (e.g., "... societal practices that affect males' versus females' freedom to explore the environment", Liben, 1981, p. 17).

Golledge (1992) suggests that wayfinding errors can occur in both the encoding and decoding of information. He gives the example of how an inaccurate sense of speed can lead to a wrong estimate of distance travelled and a wrong sense of location along a route. An incorrect memory of turns may also lead to an encoding error (Golledge, 1992). For example, a driver could forget about a turn they had made earlier which might be disorienting or cause him/her to expect an additional turn.

There appear to be two general causes of wayfinding problems described in this summary of the literature. There are the external or environmental causes of wayfinding problems and the internal or individual causes. The environmental factors are the arrangement, variation and accessibility of the environment. The individual factors are all the many intrinsic features of humans which are used in wayfinding. The information processing model of wayfinding described in Figure 3.2 will be used to describe these features; they are perception (vision and hearing), memory (cognitive maps), situation assessment (spatial ability), decision making and execution. The next two sections outline these environmental and individual factors which influence wayfinding performance. As an individual factor, the impact ageing has on performance will be described in the second section.

3.7.1. Environmental Factors Affecting Wayfinding Performance

The arrangement, variation and accessibility of an environment can influence wayfinding performance. These features affect the success with which a traveller perceives, recalls and interacts with the environment. A simple and predictably arranged environment makes it easier for travellers to generate a mental image or cognitive map of the space (Evans et al., 1984). An unfamiliar city with its streets laid out in a grid pattern may be easier to remember and travel within than a city that has a complex and unpredictable arrangement. However, variation within an environment enables travellers to distinguish between different properties. "The confusing streets of Venice become traversible after one or two experiences, since they are rich in distinctive details, which are soon sequentially organised" (Lynch, 1960, p. 102). Thus, a driver would have less trouble finding a destination in a development populated with distinct and recognisable buildings than one full of similar buildings.

Lastly, there is accessibility which refers to the ease with which a traveller can obtain information about the layout and features within an environment. Accessible environments are visible directly, or indirectly, through some representation of that space (e.g., a map).

3.7.2. *Individual Factors Affecting Wayfinding Performance*

This section discusses different individual or driver related factors which adversely affect wayfinding performance. The impact each element has on wayfinding performance is described in general terms and with respect to ageing. Figure 3.3 lists the individual causes of wayfinding problems. The variables in this diagram may have a direct or indirect influence on wayfinding performance. For example, gender may indirectly affect wayfinding through experience. The A side of the triangle lists the recursive factors that have a unidirectional influence on wayfinding and the other factors. Side B lists the variables linked to information processing performance. The impact of the C factors on wayfinding performance can be moderated by sides A and B.

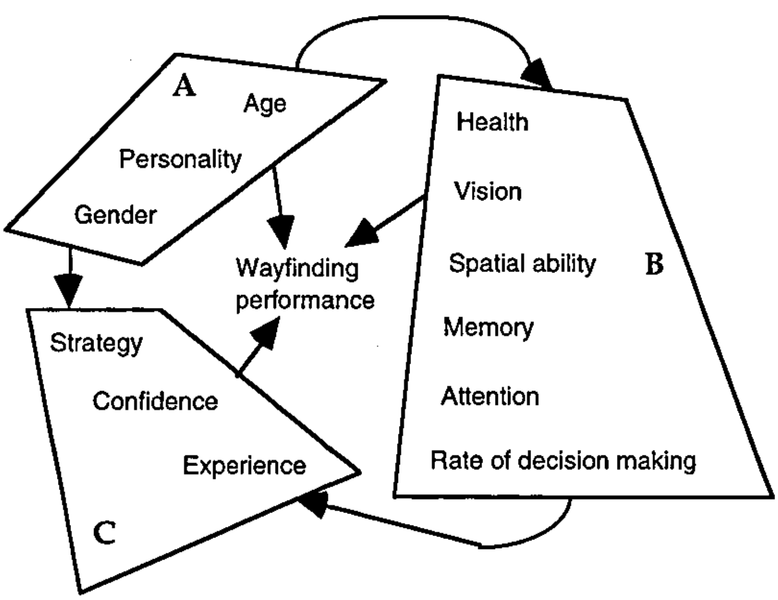


Figure 3.3. Individual influences on wayfinding performance.

Perception

When drivers encounter a decision point they must identify the appropriate path to follow. They use vision, and hearing to a lesser degree, to obtain the environmental information which is necessary for wayfinding decisions. Visual information can be obtained from outside the vehicle (e.g., road signs and landmarks) and inside the vehicle (e.g., road map and route notes).

Vision is essential to most driving tasks including wayfinding. As mentioned earlier, Gärling et al. (1986) classify built environments according to three properties that predict wayfinding problems: degree of differentiation of the environment, degree of visual access, and complexity of layout. All of these environmental characteristics can be related to visual search.

In Chapter 2, it was stated that vision is the most commonly recognised change associated with normal ageing (Small, 1987) and all dimensions of visual function decline with age (Shinar & Schieber, 1991; Smith, et al., 1993). This deterioration would certainly decrease elderly drivers' ability to extract the information needed for wayfinding. For example, McGarry (1996) found *older-elderly* drivers (65-75 years) take more time to read direction signs and are less successful at recalling sign information than *younger-elderly* drivers (50-64 years).

The impact this visual decline has on wayfinding is likely to be pervasive. All of the five dimensions of visual function that create difficulties for elderly people, as described by Kosnik et al. (1988), would be influential to wayfinding performance. These dimensions, ranging from high to low levels of visual function, are reduced visual processing speed, light sensitivity, dynamic vision, near vision, and visual search.

- With a decline in visual processing speed, elderly drivers would need more time to read information off road signs, maps and notes.

- A reduction in light sensitivity would make it more difficult to see environmental information at twilight or in the dark.

- As dynamic visual acuity deteriorates, they would have more trouble reading signs and distinguishing landmark features while moving.

- A reduction in near visual acuity would reduce the ability to read small print on a map, route notes or a route guidance system. There is also a decline in far visual acuity which would reduce the distance at which road signs and landmark features can be seen.

- Visual search difficulties would reduce the accessibility of route information from signs and landmarks.

The physical changes described in Chapter 2 may also have an impact on the perception of environmental information. The decreases in seating height and range of motion in the upper body and neck (Isler, et al., 1996; Smith, et al., 1993; Yanik, 1988) would reduce elderly driver's ability to scan their field of view. Consequently, they would be less able to perceive environmental information for wayfinding.

Although important, hearing is not as essential to driving as vision. Auditory wayfinding information can come from passenger instructions or an in-vehicle route guidance system. The significant decline in hearing thresholds and discrimination occurring with old age (Fozard, 1990) would make it more difficult for elderly drivers to rely on auditory route guidance information.

Perceptual decline in old age may also influence the ability of elderly drivers to acquire information that is critical to route learning. When travelling along a route, elderly drivers may have less access to environmental wayfinding cues because of their poorer perception. Consequently, they may have fewer cues by which to describe and recall routes.

Memory

The environmental information that assists drivers in wayfinding does not only come from their direct observations of the road environment or media representations of the environment. As described earlier in this chapter, drivers can rely to some degree on their cognitive representations of the environment retained in memory for wayfinding.

Cognitive Maps

Cognitive map information is originally derived from real maps, verbal directions or prior experience with an environment. Wayfinding performance is related to the quality of information represented in a driver's cognitive map of the route. The quality of a driver's cognitive route map is a function of their familiarity. Prior experience of a route is available to assist drivers whenever they are required to negotiate a route again. This *spatial familiarity* helps travellers "..to identify origins, destinations, choice points, check points or general layout information..." which is needed in wayfinding "...to specify the path of travel from among all possible connecting routes" (Golledge, 1992, p. 206).

Familiarity enables drivers to have detailed and accurate information of a route. A lack of familiarity, or an incomplete or inaccurate cognitive representation of a route, would lead to poorer wayfinding performance. As with a road atlas, flaws or an absence of detail in cognitive maps can cause wayfinding errors.

There has been a movement observed in the literature which explores distortions or inaccuracies in people's cognitive maps. This has been done because "...the nature of these representations is often revealed by errors of judgement and memory (Tversky, 1992). Errors and distortions in cognitive maps "...mainly arise from those features that make the representations so useful for common sense knowledge but they may also arise from the type and frequency of experience a user has with the environment" (Medyckyj-Scott & Blades, 1990, p. 5). Medyckyj-Scott and Blades list some of the distortions which seem to occur in cognitive maps. One distortion is when the actual configuration of a feature is simplified or replaced by a generic descriptor. For example, a river that in reality twists through a city may be represented in a cognitive map as being straight. Alternatively, a road junction may be remembered as being perpendicular when in reality it is not. Appleyard (1981) identified that errors in cognitive maps are mainly metrical (distance) and not topographical (relational). These distortions could lead to wayfinding errors but this apparently has not been investigated.

The formation of cognitive maps can be influenced by inter-related factors such as traveller's age, experience, stress level, mode of travel and method of planning. For example, stress, in the form of loud intermittent and unpredictable noise, can have a negative impact on learning an unfamiliar environment (Evans et al., 1984). It might be expected that elderly drivers, who tend to find driving more stressful, would have more difficulty learning an unfamiliar route.

Accuracy of cognitive maps generally improves with experience and age, but may decline in old age (Medyckyj-Scott & Blades, 1990). An age related decline in memory for spatial information is one of the most replicated findings in ageing research (Simon, Walsh, Regnier, & Krauss, 1992). This can be manifested as a decline in the ability to acquire information that is critical to route learning (Evans, et al., 1984); the ability to remember routes (Lipman, 1991), and the ability to construct an adequate cognitive representation of one's surroundings (Walsh, Krauss, & Regnier, 1981). Both types of spatial knowledge, configurational and route knowledge, appear to exhibit a decline in old age (Kirasic, 1985). This influence is particularly salient when learning unfamiliar environments.

Research on spatial memory and ageing tends to be laboratory based (e.g., Darby-Lipman & Caplan, 1992). Studies which have a more practical significance look at the movements of elderly people on foot in institutional settings or around their neighbourhoods (e.g., Aubrey & Moniz, 1996). No research has explored the relationship between age and spatial memory for driving. Furthermore, the decline that does occur may not be sufficient to influence driving behaviour. Consequently, it is uncertain whether previous research would apply to driving.

There are two obvious reasons to question the applicability of laboratory and pedestrian wayfinding research to the context of driving. Firstly, elderly drivers may not exhibit a similar decline in their spatial memory because the experience of driving may help to maintain spatial memory skills (Aubrey & Moniz, 1996). The significance of experience for wayfinding performance is discussed later in this chapter. A second reason is wayfinding on foot is different from wayfinding in a car. In some respects, wayfinding on foot is more difficult because there are essentially an infinite selection of routes, whereas in cars drivers tend to be restricted to roads. However, in other respects wayfinding on foot is easier. When driving there is a pace imposed on you by other motorists and road laws, whereas on foot you have control of the pace. As a pedestrian the problem of missing or misinterpreting signs is much reduced because there is more time to read them and it is easier to back track to a sign that was passed. Signs can also be read at a pedestrian's convenience and at whatever viewing distance they require. Another difference between wayfinding on foot and while driving is that walking may be a less demanding task. Consequently, people would have more attentional resources available for the wayfinding task when walking.

Situation Assessment

Environmental information which is perceived directly, or obtained from a cognitive representation of the environment, is used by drivers to consider their progress, orientation and route options. It is believed that spatial ability and attentional skills are required to integrate and interpret this information and are essential to the situation assessment stage of wayfinding.

Spatial ability

The principal spatial abilities that have been identified through psychometric testing are visualisation, spatial relations and spatial orientation (Kirasic, 1985). Spatial visualisation is the ability to imagine spatial displacement or movement. Spatial relations is the ability to recognise an object from different perspectives. Spatial orientation, or sense of direction, is the "...ability to maintain orientation while moving through space or the ability to point to unseen goals and draw maps" (Kozlowski & Bryant, 1977, p. 590).

Antin, Dingus, Hulse, and Wierwille (1988) investigated the relationship between route navigation performance and spatial ability. They had 32 drivers aged 18 to 73 years complete three spatial abilities tests taken from Ekstrom, French, Harmon, and Dermon (1976): Identical Pictures Test to measure perceptual speed; Cube Comparisons Test to measure spatial orientation; and the Map Planning Tests to measure spatial scanning. Participants navigated with a paper map and with a moving-map based route guidance system. The control condition was a memorised route. Navigational performance was rated on a five point scale as in Wierwille et al. (1988) described earlier in this chapter. Antin et al. (1988) found no relationship between spatial ability and navigation performance. However, drivers with higher spatial ability required less time to plan and travel their routes. The researchers suggested that a relationship between spatial ability and navigation performance may be found if more relevant measures of spatial ability were used. Although Antin et al. (1988) did not report any age or gender differences in spatial ability, it has been shown to vary in relation to both age and gender.

There is substantial evidence of an age-related decrement in spatial ability (Simon, et al., 1992). "... any age related decline in spatial abilities should have a clear and significant impact on the elderly individual's transactions with his or her spatial environment" (Kirasic, 1985, p. 185). For example, it can affect an elderly person's ability to orient themselves with respect to a map (Aubrey & Dobbs, 1989; Aubrey & Dobbs, 1990) or extract information from a in-vehicle moving map display (Wierwille, 1990). Georgemiller and Hassan (1986) describe how this decline in spatial ability contributes to a shrinking territorial range, lowered activity level, and a constricted social space; characteristics of many elderly people. In fact, they report that a clinical indication of mild spatial problems among the elderly is when they discontinue driving despite adequate visual and motor skills.

There is also plenty of evidence to suggest there are gender differences in spatial ability (e.g., Silverman & Eals, 1992). Males tend to score higher than females on psychometric tests for spatial ability (Vandenburg, Kuse, & Vogler, 1985). However, these differences do not tend to be large (Hyde, 1990). Hyde, from a meta-analysis of research on spatial ability, reports the largest difference is for tests of mental rotation. Possible reasons for gender differences in spatial ability have been outlined by Kitchin (1994): men and women have biological differences affecting their ability to understand and perform the tests; they have different ways of dealing with the same problem, using different cognitive strategies; there is a bias in spatial test measures that gives men an advantage; men and women possess different cognitive maps and information; they are taught differently and attend different courses; women positively react to stereotypes; and women have different social role constraints limiting their opportunities for environmental experience.

These gender differences in spatial test performance do not directly apply to wayfinding. Some studies have found men are better than women at wayfinding (e.g., Devlin & Bernstein, 1995) whereas others have not found any performance differences (e.g., Kirasic, Allen, & Siegel, 1984). The disparities that have been found are attributed more to contrasting strategies and experiences between the genders rather than spatial ability. "Girls learn to drive later, are less likely to have a car, when younger are generally given less exploratory freedom, and are more likely to engage in passive travelling" (Beck & Wood, 1976, p. 209). Schraagen (1990) found women performed worse than males at wayfinding in cities because they focused exclusively on street names and could not recall as many map details.

Attention

During the situation assessment stage of wayfinding travellers must attend to the environmental information that is required to support wayfinding decisions. Elderly drivers may have more trouble than younger drivers with situation assessment while wayfinding because their declining attentional skills would make it more difficult for them to consider their progress, orientation and route options.

From the discussion of age-related changes in attentional processes in Chapter 2, it is apparent that at least three different types of attention would be required in the situation assessment stage of wayfinding. Divided attention would be required to maintain safe control of the vehicle while simultaneously searching for environmental cues. An inability to divide attention between wayfinding and driving would force one of the tasks to be neglected. The neglected task is likely to be the environmental situation assessment because it has less of a priority over the task of driving safely. Similarly, attention switching would be required to alternate between wayfinding and other driving tasks (e.g., reading the instrument panel). Less efficient attention switching would make it harder to move between wayfinding and driving tasks. Lastly, selective attention would be required to distinguish information relevant or not relevant to wayfinding or the driving task. Situation assessment would prove more difficult for drivers with difficulties distinguishing task relevant information.

Decision Making

Based on the assessment of their situation, drivers must decide on an appropriate response. This might involve the decision to change paths by turning in a particular direction or to continue along the same path. As with situation assessment, attention is involved in wayfinding decision making. Because elderly people have less capacity to process information and are slower at it (McDowd & Birren, 1990) they would be limited in their ability to make wayfinding decisions while driving.

For familiar situations, drivers can rely on decision rules as with the skill-based or rule-based levels of functioning (See Chapter 2). These automatic decisions and responses would be quick and would require minimal processing and attention. For novel situations, like wayfinding in an unfamiliar environment, drivers require more time and attentional resources. The decision could require them to search their memory or seek out additional information. This decision and response selection process exhibits a number of age related changes. They can be manifested in the attentional resources, memory and rate of decision making.

The slower decision making of elderly drivers has implications for wayfinding. Fast wayfinding decisions are often required because driving is a paced task. Consequently, once a driver has assessed their situation, they may not have enough time to make a decision before the opportunity to execute that decision has passed.

Execution

Once a decision is made, drivers must execute it at the choice point. Execution of a wayfinding decision might involve changing lanes, turning, stopping or continuing along the same path. These manoeuvres are only likely to be difficult for inexperienced drivers or when there is a limited window of opportunity to perform them successfully. For example, a driver would have trouble exiting a motorway if there is only 50 metres of slip road remaining.

As described in Chapter 2, some of the physical properties of response execution show a decline with age. This is because adults initiate and execute movements more slowly and with less precision as they age (Stelmach & Nahom, 1992). Elderly drivers, because of these changes probably require more time and advanced warning to perform wayfinding manoeuvres. They are likely to experience problems when they have to make quick manoeuvres without warning.

Additional Factors

Experience

There are a number of other individual factors which can influence wayfinding performance and many of these factors can also be associated with ageing. One of the most significant is experience. Studies have shown experience may compensate for age related deficiencies in wayfinding ability. Hill (1992) investigated the spatial competence of elderly hunters in Nova Scotia. From the search and rescue reports, he found that there were significantly fewer elderly hunters (+65 years) getting lost than would be expected in comparison to younger hunters (controlling for numbers). He attributed the difference to the elderly hunter's experience navigating in the wilderness.

Aubrey and Moniz (1996) have taken another perspective on driving experience and wayfinding ability. They argue that experience on a task like driving, which places high demands on spatial wayfinding skills, would be a good predictor of wayfinding performance on foot in an unfamiliar environment. They compared wayfinding performance in a building of 13 elderly female non-drivers with 23 drivers (mean age of 73 years). Performance was measured in terms of route choice, time, stops and backtracks. The elderly female drivers were better at wayfinding in an unfamiliar building than the non-drivers. Aubrey and Moniz (1996) conclude that "...spatial activities engaged in during adulthood are important for the maintenance of good general wayfinding skills in later life" (p. 4).

Schraagen (1990), in his study of 24 people driving in an unfamiliar city, found driving experience did not relate to navigation performance. This result is contrary to expectations. However, on further consideration it is apparent that a distinction should be made between basic driving experience and driver wayfinding experience. A person can have driving experience without having a great amount of wayfinding experience. For example, they may restrict their driving to commuting on familiar routes and rarely drive to any unfamiliar destinations.

Despite Schraagen's (1990) research, driving experience and performance are likely to be important for wayfinding. Experts who find driving less demanding, from their automation of the driving task, should have more resources available to attend to the wayfinding task. Alternatively, limitations in driving ability would make it more difficult for a person to reach their destination. For instance, an elderly driver who has trouble turning across traffic flows may have restricted route options.

Experience does have an affect on map reading (Williamson & McGuinness, 1990). Williamson and McGuinness (1990), from an analysis of map comprehension, concluded that a good knowledge of physical environment leads to a better understanding of maps. The same probably applies to wayfinding. Experienced navigators would have more developed global schema. This better understanding of wayfinding and the general geometric regularities of road networks would improve the success with which drivers interpret wayfinding information. Experienced people have more information from global schema at their disposal, thus they should be more prepared for wayfinding in unfamiliar settings.

Another important dimension of wayfinding experience is practice. Although a person may have had plenty experience of wayfinding in an unfamiliar environment, they may lose the skill if it is not maintained through practice. This could be a factor contributing to elderly drivers' aversion to driving on unfamiliar routes. Elderly drivers may find it more difficult to negotiate unfamiliar routes because they drive less and, as a consequence, do not get the necessary practice.

Strategy

Strategy is another factor that should be considered in the assessment of individual variations in wayfinding performance. There are different planning strategies that match the two different levels of spatial knowledge. Some people may plan routes which are a linear combination of choice points whereas others try to learn the configuration of an area (e.g., Schraagen, 1990). As with using maps and notes, both of these strategies have their advantages and disadvantages.

There are also different strategies for wayfinding while en route to a destination. Travellers have different sources of environmental information to which they can attend to while driving (e.g., map, route notes, passenger instructions). Wayfinding performance should be dependent on the strategies drivers employ.

Social and Personality Factors that Affect Wayfinding Performance

Social mediation can have an effect on wayfinding because people typically experience unfamiliar environments in the company of others (Blades, 1991). Beck and Wood (1976) have identified different social approaches to wayfinding. Young people visiting an unfamiliar city were classified according to three groups: *fixers, mixers* and *rangers*. *Fixers* preferred to stay close to their hotel and were reluctant to explore unless they were being guided along. *Mixers* liked to explore as long as they were in a social group. Lastly, there were *Rangers* who were keen to explore as individuals or in small groups.

Beck and Wood's (1976) personality types may apply to driving in unfamiliar environments. The fixers would prefer not to drive to unfamiliar places. They would only go if another person was driving and they were not responsible for navigation. The mixers would drive to unfamiliar destinations as long as they were travelling with others. The rangers would readily travel alone to unfamiliar destinations.

Confidence is likely to be an important factor affecting these different exploratory personality types. People who are more exploratory must have more confidence in their wayfinding performance. Confidence in one's ability may be important in wayfinding. Driving into the unfamiliar might seem less challenging or threatening to a driver who has a high level of wayfinding confidence. Confident way finders would believe there will be no surprises and that they can overcome any wayfinding challenge. They may even feel familiar with an unfamiliar environment. This confidence would come with experience and may be influenced by other aspects such as personality, age and gender.

An inclination towards risk taking or sensation seeking may have a similar effect on peoples' willingness to explore. People who avoid taking risks may be averse to travelling to unfamiliar places. Zuckerman (1979) designed a questionnaire to measure *Sensation Seeking* personality. The *Sensation Seeking* scale asks respondents to choose between a series of 40 matched statements which best describe their preferences. Two sets of statements on this scale relate to wayfinding adventurousness.

6. A. *I like to explore a strange city or a section of town by myself, even if it means getting lost.*
   B. *I prefer a guide when I am in a place I don't know very well.*
18. A. *I would like to take off on a trip with no pre-planned or definite routes, or timetable.*
   B. *When I go on a trip I like to plan my route and timetable fairly carefully.*

As mentioned in Chapter 2, there is a belief or perhaps a stereotype that elderly drivers tend to be less confident and risk averse (e.g., Rothe et al., 1990). If elderly drivers do indeed lack confidence and have an aversion to risk, it would probably have a negative impact on their wayfinding performance. However, this remains to be demonstrated.

3.8. Chapter Conclusions

A prerequisite to finding a solution to the wayfinding problems of elderly drivers is to understand these problems and identify them. Although no research has been found that seeks to determine the nature of these problems, it is known that they are sufficient to deter some elderly people from driving unfamiliar routes (Sixsmith, 1990). The specific type of problems they experience are unknown. Based on the information presented in this chapter and Chapter 2, some predictions can be made about the sort of navigational problems elderly drivers experience.

It is believed that, as a consequence of declining spatial ability, elderly drivers are more inclined to have problems with extracting information from road maps and having to rely on their cognitive representations of routes. It is suspected that elderly drivers may take longer to choose routes, and to learn and remember new routes. Elderly drivers may also take longer to read maps, may miss information on road signs, and fail to gain information from landmarks as a consequence of the decline in their visual acuity and restricted visual field. Lastly, with fewer attentional resources and slower psychomotor performance, it is suspected that elderly drivers may sacrifice either navigational performance or driving performance at the expense of the other. For example, when faced with a navigational decision drivers may have to slow or stop their car in order to reduce attentional demands or to provide more time to make a decision. Alternatively, a driver may postpone their navigational decision, in order to concentrate more on controlling the vehicle, until they have sufficient resources available to make the decision.

At present, only speculations can be made about the sort of navigational problems elderly drivers have. Research needs to be conducted to examine this phenomenon in more detail. Research also needs to be performed to assess the impact these problems have, if any, on the mobility of elderly drivers. It is possible that navigational problems among elderly drivers are only of minor significance. This needs to be determined. The following chapters describe research that addresses these outstanding questions.

Chapter 4: Focus Group Discussions

4.1. Chapter Summary

This chapter reports a preliminary investigation into driver wayfinding. Focus group discussions and a questionnaire survey were conducted with elderly (over 60 years) and non-elderly drivers.* Topics included wayfinding strategies, problems and new route guidance technology. Results suggest elderly drivers generally have more problems wayfinding than non-elderly drivers and tend to be less confident in their wayfinding ability. Difficulties with wayfinding could deter them from undertaking a trip to an unfamiliar place. The problems seem to relate to a lack of information, mainly in the form of signage and a road system designed without consideration of elderly drivers. Solutions to these problems are proposed based on suggestions from the participants and wayfinding theory.

4.2. Introduction

Some elderly drivers have problems wayfinding. Wayfinding refers to the dynamic step-by-step decision making process that is required to negotiate a path to a destination (Golledge, 1992; Passini, 1984). It is believed age-related changes make wayfinding more difficult for elderly drivers (see Section 3.7.2). For example, the effects of ageing on field of view, rate of information processing and spatial ability would make it more difficult for elderly drivers to obtain the information necessary to support navigation decisions while driving.

Wayfinding problems are considered to have negative implications for road safety and mobility. They may also contribute to psychological stress

* The main results of this research were presented at *The 7th Conference of the New Zealand Ergonomics Society* (Burns & Galer Flyte, 1996) .

and wasted time and fuel. Furthermore, the seriousness of these implications will increase as the number of elderly drivers and their dependency on cars for mobility and independence also increases.

Studies have investigated the problems elderly people have wayfinding (e.g., Lipman, 1991) but not in a driving context. Research on wayfinding while driving in general is limited, irrespective of age. There has only been minimal research on the strategies people use to find their way while driving and the problems they experience (Mark & McGranaghan, 1988). More research is necessary because the designers of in-vehicle route guidance technology will require this information if they are to meet drivers' wayfinding needs.

There is a need for research to identify and understand the particular problems elderly drivers have with wayfinding and to find what solutions and approaches are appropriate. The study reported in this chapter was conducted to gain a qualitative awareness of these problems as elderly drivers see them. The limited knowledge in this area necessitated a flexible and exploratory method for conducting a preliminary examination of the issues. Focus group discussions were chosen as the most appropriate method. Focus groups involve bringing people together to conduct a form of collective interview. This method allows researchers to interact directly with respondents and provides an opportunity to obtain large and rich amounts of data (Stewart & Shamdasani, 1990).

Other research on elderly drivers has employed the method of focus groups with success. Sixsmith (1990) held focus group discussions with 47 older drivers aged 52 to 79. Her research sought to understand elderly drivers' opinions, attitudes and evaluations of new in-vehicle technologies. Six discussions were held in groups of 6 to 10 people lasting up to two hours. Participants were recruited by word-of-mouth and through organisations representing the elderly. Audio recordings of the discussions were made and transcribed later. Content analysis of the transcripts progressed according to themes which emerged during the discussions. The use of focus groups as a research method was evaluated as being " a useful vehicle through which to access thoughts and feelings on driving experiences..." p. 47.

Rothe et al. (1990) held focus group discussions with 162 elderly Canadian drivers aged 55+ years. The discussion schedule focused on issues of "...driving patterns, views of self and stereotyping, driving difficulties, perspectives on cars, licensing, and driver re-education" (p. 157). They held 31 focus group sessions with about five people per group. The age and gender distribution represented the licence statistics of the province. They were recruited through radio announcements, random dialling and notices in seniors' centres. The sessions were recorded on audio tape and by two observer-coders who transcribed comments on partially pre-coded forms. This method was needed to handle the large amounts of data. Problems with this method were that detail was lost in the pre-coding and the presence of the observers may have intruded on the discussions. These discussions were held to complement a large postal survey of older drivers and individual interviews.

In the present study, focus group discussions were held with elderly and non-elderly drivers. Non-elderly drivers were included as a comparison group which could help identify any age specific effects. Participants discussed their driving experience and behaviour, methods of route planning, wayfinding strategies and problems, and route guidance technology.

The aims of this study were to explore elderly peoples' strategies and problems with navigation in the context of driving, to explore solutions to navigation problems, and to provide preliminary information in preparation for the postal survey of drivers (see chapters 5-7).

4.3. Method

4.3.1. Participants

Four focus groups were organised to obtain information about driving, wayfinding and new route guidance technology. There were 30 participants in total, 17 of whom were male and 13 female. All held valid driving licences. Three of the four groups consisted of elderly drivers whose ages ranged from 59 to 82 years ($n = 22$, $\underline{M} = 68.5$ years). They received their driving licences between 1926 and 1961. For comparison, a focus group was also held with non-elderly drivers whose ages ranged from 24 to 47 years ($n = 8$, $\underline{M} = 34.5$ years). They received their driving licences between 1966 and 1993. Participants had been driving regularly for between 2 and 61 years (M = 32.1, SD = 17.8 years).

Two of the discussion groups were held in Canada and two were held in England. Both of the Canadian groups were elderly. Participants were recruited through volunteer groups and from a database of subjects. They were paid for their involvement in the discussion groups.

4.3.2. *Procedure*

Focus Group Discussions

A schedule was prepared in advance in order to guide discussions and to ensure certain issues were covered by every group (see Appendix A). The moderator's role was to introduce items on the discussion schedule. There was no fixed order to the items on the schedule and the moderator could encourage discussion of those items that arose naturally without prompting during conversation. Where possible, the moderator would survey the views of participants to highlight points of consensus or contention.

Discussion groups were held with Canadian and English drivers. It was believed the different driving conditions between these two countries would help to provide a better understanding of wayfinding. Some issues would be unique to each country; for example, winter driving in Canada would present different concerns than in England. However, it was also expected there would be some issues which transcend culture, climate and road system. The discussion of these common issues might give insight into the fundamentals of wayfinding. There was also some interest in whether the results of research on English drivers could be applied to North America.

Discussions were recorded on an audio cassette recorder and transcribed later. They were set to last 90 minutes with a short coffee break half way through. Participants were seated around a large square table. They were asked to introduce themselves and briefly describe their driving experience. This was done to help the experimenter identify speakers' voices for the subsequent transcription of recordings and helped to introduce participants to one another.

The first item of discussion proposed by the moderator asked people to describe how they found their way to the building where the discussions were being held. This topic, which was common to all participants, was also used to ease the group into a discussion.

The next discussion point on the schedule asked participants to describe their last trip to an unfamiliar place or a memorable trip to an unfamiliar place. The moderator prompted the discussion when necessary with questions about trip plans, wayfinding strategies and problems. The second topic was about the methods drivers use to plan routes in advance of going on an unfamiliar trip (e.g., read a map or make notes of the route). Participants were asked to describe the methods they used. They were also asked about all the possible methods which could be used. Details of how their preparations changed with respect to experience and type of unfamiliar trip were also discussed.

The next topic of discussion was the methods drivers used to find their way while driving along an unfamiliar route (e.g., rely on passenger's directions or follow notes of the route). Here they were prompted to discuss their problems, solutions, opinions and experiences with respect to maps, road signs, sense of direction and following directions. Participants were also encouraged to discuss situations where they could not find their destination or lost their way while driving there. Causes of getting lost and types of wayfinding errors were explored. The consequences of getting lost were also discussed (e.g., stress and embarrassment). The final topic of discussion was navigational aids. Participants were asked to describe how conventional wayfinding could be improved. They were also asked to consider the potential for new route guidance technology to help them find their way while driving. Concluding comments were noted and they were asked to complete a questionnaire.

Questionnaire Survey

Participants in the discussion groups were asked to complete the questionnaire and return it by post. The questionnaire consisted of 32 questions in total. These focused on demographic information, driving patterns, experiences and wayfinding strategies. It also served as an pre-pilot to the questionnaire used in the survey described in Chapter 5.

4.4. Results

4.4.1. *Focus Group Discussions*

Complete transcripts of the recorded discussions were made. The content of the discussions was reviewed and classified into themes based on the original discussion schedule. Organising the data along these scheduled themes ensured the analysis was structured from the data rather than post hoc classifications made by the researcher (Sixsmith, 1990; Stewart & Shamdasani, 1990). There were 125 pages of transcribed text which amounted to almost 55,000 words of discussion. Complete transcripts of the discussions cannot be included, however examples are presented to describe the range of opinions and main points which were found to be repeated across the groups. Details are given about issues relating to driving in general, wayfinding strategies, wayfinding problems, the implications of wayfinding problems and route guidance technology.

Driving

Attitudes about driving varied considerably among the respondents. In particular, female Canadian drivers seem to enjoy driving more than their English counterparts. Some relevant quotes from the discussions are presented in italics below. They are identified by nationality and age group. The acronym beside the quote describes the person: O (old), Y (young), E (English), C (Canadian), F (female) and M (male). Thus, OEF refers to an elderly English female.

OEF *driving conditions being what they are today - I don't get a lot of pleasure from it*

OEF *there's no pleasure in driving - really there's just too much hassle*

OCF *to be able to drive is really wonderful*

OCF *I hope that I can keep on driving for a number of years - and so far it's been good*

A common concern among the respondents were driving conditions. Below are descriptions of some conditions and situations they preferred to avoid.

YEM *I have problems when the sun is in the wrong place*

OCM *I've struggled through ice storms and snow storms and that for 30 years - I don't want to do that anymore*

OEM *I find cities just very very difficult and try to avoid them*

OCF *I'll drive it* [motorway] *- only I don't like it in rush hour - I think you're just asking for trouble*

OEM *it's best like if you can avoid shops and shop hours and office hours*

OCF *it's one thing you do avoid is driving at night*

OCM *I avoid highway driving in the dark*

OCM *I find dusk is a difficult time...*

OCF *that's the worst time of all*

The elderly participants highlighted a number of changes they experienced over the years. Slower response time and concerns about increases in the speed of traffic were a common concern among the elderly English drivers. Slower response times also contributed to wayfinding errors such as missing a turn.

OEM *yeah - we got some younger passengers in the back who were more alert than we are*

OEM *you just don't take it in as quick as you get older - I find that - I mean they're* [younger drivers] *really sharp compared with me*

OCM *when you get older you're not quite as quick off the spot as you are when you're younger*

OEM *turn the clock back...when you was going down the road about forty miles an hour you was battling along - you wind it up to fifty and you're flying - you look today - the car's just cruising at fifty-five to sixty*

OEM *fifty was* ***fast*** *when I started to drive*

OEF *I do think the younger generation find it easier to drive because they have not experienced the times we had*

OEM *everything is so much faster - there's more traffic and there's so many more signs to see ... I don't keep up with them*

OEM *well it's too fast everywhere*

Wayfinding Strategies

A variety of different methods to prepare for unfamiliar trips were mentioned by the drivers. They studied maps in advance, made detailed notes about the route, consulted someone who knew the route, contacted a motoring organisation, used a computer based route planner, and did practice trips.

OEF *I think it's a good idea to look at the map before you go to at least have some idea of where you are going*

OEM *make a few notes on a piece of paper and make 'em big so you can read them without holding them*

OEM *make a few notes - a few landmarks - pick out a few things along the way*

OCF *if I'm going some place in the city I will phone the place and ask them*

OCF *the maps* [motoring organisation strip maps] *are wonderful - we don't go anywhere without them*

Did anyone have any trouble driving here?

OEM *no 'cause we had a dummy run yesterday*

YEM *I had foolishly not taken a map because I had these wonderful directions that came from a computer so they must be right*

YEF *I planned this out really carefully - had it all written down - you know - to join that road at that particular junction*

Aside from following road signs and route plans, a number of additional strategies for wayfinding while driving were mentioned. Drivers followed directions from a passenger, asked local people for directions, or relied on a compass when necessary.

OEM *you're going to some place you haven't been to before and you're sitting with your wife and she looks at the map and she tells you where to go*

OCM *we've always travelled in tandem - my wife is a good navigator*

OCF *I'll stop and ask someone walking down the street*

OCF *I have a little compass ... it can be helpful - you know just to tell me what direction*

YEF *I always try and find a taxi rank or a post office*

Wayfinding Problems

The participants identified a broad range of wayfinding problems. Some of the more prevalent difficulties were turning in the wrong direction, missing turns and having trouble getting precisely to a destination.

OCF *oh yeah it* [missing a turn] *happens often*

OEF *we've done that* [missed a turn] *many times*

OEM *I think often you know where to go but you can't get through*

YEM *I just couldn't find a way of getting to that particular street*

YEM *I went the wrong way on the M25*

There were many different locations where wayfinding problems occurred. The most common locations were cities (especially one-way streets) and road work detours. The English drivers expressed more problems with wayfinding in cities than did the Canadian drivers.

OEM *Birmingham - I know I'm going to get lost with racing certainty*

OEM *we followed it* [a detour] *around for 40 miles and ended up back where we were two hours later*

YEM *I was navigating around some back streets in Leicester ... and one thing I kept finding was one-way streets that I wanted to turn the wrong way into*

Upon making a wayfinding error, drivers tended to know what their mistake was and were able to correct the error.

OEM *I could see it out of the corner of my eyes - I should have gone that way*

When drivers actually did get lost they tended to stop and ask for directions or kept searching to get back on track.

OCF *if I'm on a main road I'll turn off the first exit and then study my map or go to a garage*

OCF *I stopped in a grocery store and bought a city map*

OCF *I went into a pizza place that delivers to the whole area and they were able to direct me to where I wanted to go*

YEF *I can never remember what they say*

YEM *got there by process of interpolation - going around and around in smaller circles*

Wayfinding errors were attributed to both environmental and individual causes. Among the environmental causes of wayfinding problems there were: inadequate or non-existent signage, inaccurate signage, obscured signage, bad directions, busy roads and out of date or inaccurate maps.

OEM *they* [signs] *assume you know where you're going*

OCF *I can't see them* [signs] *- when I do get up close enough it's too late*

OCF *the other day I had to park my car - get out and look*

OEM *I've no doubt that there were signs up but I never noticed them*

OEM *you come up to there and there's no sign post ... you take potluck which way to go*

OEM *road signs placed behind tree branches*

OCF *the exit numbers are placed right beside the exit - which to my mind is suicidal - you know - you should know the exit's coming up - not as you leave*

OEM *I've got a map of Birmingham and it does actually bring me to ... the street I want - but going through there - the volume of traffic - you just slip up*

OCF *you're watching the traffic and you can't keep an eye on the street signs no matter how large they are*

OEM *another little annoying thing is the staggered junction ... only taking up 50 yards or something like that and they don't show up on a map - it's just straight across*

YEM *I got lost a while ago in Derbyshire - I was told to turn left at a certain pub and they had changed the name of that pub*

Some of the individual causes mentioned were poor sense of direction and absentmindedness or inattention.

What caused you to become lost?

YEM *sheer inability to navigate*

YEM *I've missed turns before because I was too busy looking for speed cameras*

OCF *I have no sense of direction ... my husband used to go the opposite direction to what I said because I was always wrong*

OEM *we set off and after about ten minutes I said to my wife would you mind telling me where we're going*

Wayfinding problems seemed to occur when drivers encountered things contrary to what they had expected.

OCF *I thought it was a seniors' home and my god it wasn't at all - it was a great big new posh building with offices and things ... I finally found it - but I had three runs at that*

OCF *I was on a street the other day and it* [the numbers] *was opposite of what I thought it should be*

OCF *generally you go to the right because most exits are off to the right - but it's not always the case*

OCF *Ottawa's hard because you have streets that have three names*

OCM *in a community where the streets are not laid out in parallel - there always seems to be less rhyme or reason to which way the streets are going to go*

YEM *sometimes you get to a roundabout and you don't go straight you have to go left and I'm thinking you just drive straight and that's why I end up getting lost there*

Many of the elderly drivers expressed how important confidence was to successful wayfinding. The statement below exemplifies this common view amongst the elderly drivers.

OCF *I find it* [phoning for directions] *very helpful and it gives me more confidence...I think one of the things good drivers need at all ages is confidence and that anything that increases your confidence in yourself - if you get there safely - is gonna be a little old strategy*

Uncertainty is related to confidence. Having confirmatory information (e.g., from a sign) that reduces uncertainty was considered to be beneficial.

OCF *after you make a choice it's really nice to see highway whatever* [on a road sign]

Implications of Wayfinding Problems

The discussion also identified some of the implications of wayfinding problems. The most common implications mentioned were stress, fear and embarrassment.

YEF *that really stressed me out - trying to find my way to an unfamiliar place when the traffic's heavy*

YEM *I got really upset - I was swearing and cursing blindly the road builders and generally feeling militant about the whole thing and yeah I was upset - no longer rational*

YEF *I'm sitting there and I'm thinking - I don't know where I am - you start sweating and you panic ... it's not just the stress of being late - it's also the stress of being lost*

YEM *it can be intensely embarrassing as well - when you go the wrong way and everyone in the car goes blah - especially somewhere that you know*

OEF *the waste of time is the biggest thing really - isn't it - if you get lost you waste time*

OCF *I was lost in Toronto several months ago and it was midnight - I really had to be careful*

New Route Guidance Technology

The respondents discussed their views on the potential uses, benefits and problems of route guidance technology. They also discussed how they would like route guidance information to be displayed to them. Below is a selection of some comments that were made.

OEF *we're a bit old for that sort of thing*

OEF *I think if you've got someone telling you what to do - you would certainly be more adventurous*

OEM *I don't really think that by the time it came to be that any of us would be interested*

OCF *this is what I worried about - how difficult the programing is going to be*

OCF *I would have problems programing the computer*

Do you think it would help to get some sort of visual information?

OEM *no because as soon as you introduce visual into it - you are taking your mind off the main thing - that's where you're driving*

OEF *voices much easier than having to look at something*

OEM *the problem is I'd have a job hearing it with the old wife chattering away*

Would you want a route guidance system?

OCF *no no*

OCF *well - it would depend if it would work*

OCF *oh I would because I have such trouble with the directions*

4.4.2. *Questionnaire Survey*

Each of the 30 participants completed the questionnaire. The following section presents a summary of their responses.

Driving Frequency

All drivers reported driving at least once a week: 25 drove most days, 4 drove more than once a week, and only 1 drove once a week. A *t*-test for unrelated groups indicated the non-elderly drivers drove on significantly more trips per week than the elderly drivers, $t(27) = 2.54, p < 0.05$. Although, the elderly drivers were retired, it was known the majority of Canadian participants were active in volunteer work.

Fourteen drivers reported going on trips to unfamiliar destinations at least once a week. The remainder of respondents reported driving to unfamiliar destinations less often. Four drivers (all old and English) said they drove to unfamiliar destinations less often than three times in a year. However, there was no significant difference in the number of unfamiliar trips per week between the elderly and non-elderly drivers.

All of the non-elderly and 14 (64%) of the elderly drivers reported driving at night more than once a week, whereas the remaining drivers drove at night less frequently. Only one of the elderly respondents had restricted access to a car. This person relied on a bicycle for transportation when his spouse was at work with the car. When given the option to drive or be a passenger, half of the elderly and only one of the non-elderly respondents preferred to be a passenger. Also, elderly drivers tended to drive with a passenger more often than the non-elderly ones.

Driving Activities

Respondents were asked to list the main reasons they have for driving. There were two interpretations of this question. Respondents identified the incentive or motive they had for driving. There were four categories of incentives: pleasure (7), convenience (5), independence (2), and preferred or only means of transportation (6). Respondents also listed a variety of activities as reasons for driving. Six respondents only stated incentives as reasons for driving and 22 respondents listed activities. Seven respondents listed both incentives and activities. There were 6 categories of activities stated as reasons for driving: shopping (13), social visiting (14), holidays (5), work (12), errands (7), and recreation (4). Driving was the most common method of getting about locally for elderly and non-elderly respondents (24). Walking, buses and bicycles were the other most common alternatives to travelling locally by car.

Situations Avoided

Respondents reported a number of different driving conditions they preferred to avoid; 14 (12 old, 2 young) preferred to avoid bad weather conditions with slippery road surfaces and poor visibility (e.g., snow, rain and icy roads). Eleven elderly respondents preferred to avoid night or twilight conditions because of restricted visibility and glare from on-coming cars. Seven respondents (6 old, 1 young) avoided motorway driving. Elderly respondents did not like the high speed traffic of motorways, long distance driving without breaks and *hassles from lorries.* One elderly subject did not like motorway driving because they found it tiring and another found it boring. Eleven respondents (6 old, 5 young) preferred to avoid rush hour driving conditions. Elderly respondents found rush hour driving stressful because of traffic and did not like the impatience of other drivers or the perceived accident risk. Individual respondents reported they did not like driving on unlit roads at night, in city centres, on long night drives, through unfamiliar areas at night and after a long days work.

Health

No respondents rated their hearing or vision as being poor. However, six elderly respondents reported health problems which may interfere with their driving (e.g., heart trouble, cataracts, and arthritis). No younger drivers reported these problems. All respondents said they kept physically active with activities ranging from walking to curling.

Mobility and Independence

Table 4.1 shows the responses to the question: *How would your life change if you could no longer drive?* Respondents could answer either *Yes* or *No* to each of these questions. Space was provided to insert *other* consequences of no longer being able to drive. Among the *other* responses to this question, one participant said they would use taxis and friends to drive them around if they no longer had a car. Two said they would use a bicycle to get about. Another said they "...would move to across the country to live with family". One person said "no longer being able to drive was one of their greatest fears of ageing". None of the younger drivers gave additional responses.

Table 4.1 How would your life change if you could no longer drive?

Would you....	Young (8)	Old (22)
rely on other forms of transport?	8	20
have to move elsewhere?	1	3
be less independent/free?	7	15
stay closer to home?	4	9
be less social?	1	8
have to change your lifestyle?	6	15
be less mobile?	4	14

Planning Strategies and Wayfinding

Respondents were asked to identify how they planned trips to unfamiliar places and how they found their way while driving. The trips were divided into an unfamiliar long distance trip and a trip within an unfamiliar city. Results are presented in Table 4.2 and Table 4.3. There were no significant differences between the number of planning and wayfinding strategies employed by non-elderly and elderly drivers. Also, they generally employ the same strategies to plan routes and to find their way while driving. An exception is that non-elderly drivers never reported using information from motoring organisations to plan routes.

Table 4.2 Route planning strategies of focus group participants.

Within a large city			100 km away			
Young	Old	Total	Young	Old	Total	
5	14	19	8	22	30	Consult road atlas or map.
8	17	25	4	11	15	Consult a street map.
0	5	5	0	8	8	Consult a motoring organisation.
4	11	15	5	11	16	Ask a friend or relative.
0	1	1	1	1	2	Try to find a way without pre-planning a route.
3	1	4	2	1	3	Other.

Table 4.3 Wayfinding strategies of focus group participants.

Within a large city			100 km away			
Young	Old	Total	Young	Old	Total	
4	17	21	5	15	20	Follow directions from a passenger.
5	10	15	4	8	12	Consult a street map while driving.
2	3	5	5	8	13	Consult a road atlas while driving.
0	5	5	0	5	5	Make a sketch of the route.
4	11	15	5	16	21	Make a list of road numbers/ landmarks/towns etc.
2	3	5	4	5	9	Rely on memory.
2	2	4	1	2	3	Other.

4.5. Discussion

4.5.1. *Driving Activities*

The elderly drivers expressed diverse opinions about driving. Some enjoyed driving whereas others preferred to avoid it altogether. Problems occurred with bad weather, in cities, rush hour traffic, dusk and night driving. These problems are consistent with what has been reported in other research (e.g., AA, 1988; Carp, 1971; MTO, 1994; Rabbitt, Carmichael, Jones, & Holland, 1996; Rothe, et al., 1990; Simms, 1993; Yee, 1985).

As expected, non-elderly drivers reported in the questionnaire that they drove more often than elderly respondents. However, there was no significant difference for the number of unfamiliar trips taken. The mean number of unfamiliar trips per week was larger for the young group of drivers although there was a large variation in these values for both groups. The absence of a significant difference is probably due to the fact many of elderly drivers in this study were active with volunteer organisations. In this respect, they may not have been representative of the overall population of elderly drivers.

Elderly participants tended to drive with a passenger more often than the non-elderly drivers. This must be partially due to differences in their car use. The non-elderly drivers would be using their cars to commute and this would be done alone. Elderly drivers would drive for shopping and social reasons. These activities would often be done with a partner.

All respondents were very dependent on car travel, even for local journeys. The importance of driving was revealed from answers in the questionnaire and content of discussions. Most respondents believed no longer being able to drive would lead to a loss of mobility and independence.

Nationality

The content of discussions identified differences across participant nationality. The English drivers expressed more problems with wayfinding in cities than did Canadian drivers. Differences in layout and traffic patterns between Canadian and English cities may be attributable to these problems. Canadian cities (e.g., Ottawa) tend to have a grid layout with their streets running parallel or at right angles to one another. The street layout in Britain tends to be less regular (e.g., London). As mentioned in Chapter 3, a city that has its streets laid out in a grid pattern would be easier to remember and travel within than a city that has a complex and unpredictable arrangement. Also, city streets tend to be narrower in England than in Canada. Driving in restricted space may place more demands on drivers, reducing their ability to attend to wayfinding.

Roundabouts represented another national difference in the content of the discussions. Roundabouts, being a more significant feature of road geometry in the U.K., were a common topic of discussion in the English groups. Also, the fast speed of traffic was a greater concern for elderly English drivers; probably because speed of traffic in the U.K. is faster than in Ontario. For example, motorway speed limits are less in Ontario (maximum 100 kph or 62 mph) than they are in the U.K. (maximum 70 mph or 113 kph).

Results indicated a Canadian/English difference in attitude about driving for female drivers. The female Canadian drivers appreciated driving and were grateful for the independence it provided. The English women described it as an obligation which they preferred to avoid. This was more likely the product of sampling and their car use rather than national differences. The English women mainly identified themselves as housewives whereas the Canadian women identified themselves as volunteer workers. Consequently, they may have attached different values to driving because they were using their cars for different activities. Attitudes may have been more alike between nationalities if the women had had comparable lifestyles. However, this diversity in the samples had the advantage that it enabled a wider impression of drivers' attitudes.

4.5.2. Route Planning Strategies

A variety of different strategies for planning and driving on unfamiliar routes were mentioned in the discussion groups. These strategies varied according to the type of trip being taken (e.g., distance, time and place). The most common strategy was to take notes of the route from a map prior to departure. This is consistent with previous research (e.g., Streff & Wallace, 1993). No age differences for the strategies employed were apparent in a content analysis of the discussions. However, elderly drivers emphasised the importance of seeing a route overview before starting. Elderly drivers also reported they were using the same wayfinding strategies they had used throughout their lives.

From the questionnaire data, more elderly drivers preferred to have navigational assistance from a passenger than non-elderly drivers. This was especially true for unfamiliar trips within cities. Another difference was that non-elderly drivers never reported relying on motoring organisations to plan trips. This could be because a smaller percentage of non-elderly drivers belong to motoring organisations.

Elderly drivers reported that difficulties with wayfinding would deter them from undertaking a trip to an unfamiliar place. This is evidence for a link between wayfinding problems and reduced mobility. The discussion groups also identified some of the implications of these problems. The most common implications mentioned were stress, fear and embarrassment.

4.5.3. *Wayfinding Problems*

An effort was made to explain some of the problems participants had experienced while trying to find their way. It would appear, from the theoretical model of driver wayfinding presented in Chapter 3, that perception and situation assessment are the most problematic parts of the wayfinding task for drivers. According to the model, when drivers encounter decision points they need to resolve the uncertainty of having more than one path option. Information drivers use to assess their situation and choose a path must be recognised from their perception of the environment or their cognitive map. This information is used to assess their progress along a route, orientation and path options. Once they have assessed the situation they select a path and direction in which to travel. After this decision, drivers must perform the actions necessary to follow their chosen path at the decision point.

The two general types of driver wayfinding problems identified in this study were a lack of information and inaccurate information. These problems were caused by features of both the individual and the environment. Drivers seemed to have trouble when there was insufficient directional information in the environment to assess their situation. For example, some elderly drivers reported having trouble when there was no sign to show them where to go. Alternatively, there were situations where information was available but it was insufficient to eliminate uncertainty. For example, an elderly driver reported a situation where he was able to identify the correct road from a sign but not the appropriate direction.

A problem for elderly drivers was the inability to decide or execute a manoeuvre in time. For example, they reported seeing signs too late for them to respond with an appropriate manoeuvre. The absence of information could have been due to their individual failure to detect or process that information prior to the decision point. For solutions however, it would seem more constructive to attribute these mistakes to environmental factors which can be more readily accommodated rather than blaming the drivers. That is, the signs were seen too late because they were poorly positioned or were too small to read from a distance.

Confidence was another individual factor relating to insufficient wayfinding information. Elderly drivers expressed the belief that confidence was important to wayfinding. They needed confidence in both their driving and wayfinding abilities to travel on unfamiliar trips. When there was a lack of confidence, doubts set in which caused them to emphasise the elements of uncertainty associated with a wayfinding decision. The consequence was their decisions became more difficult and they had to seek out additional information. Drivers lacking in confidence needed more information.

Wayfinding problems were also attributed to inattention and a poor sense of direction. Inattention would cause drivers to miss information in the environment. Wayfinding would therefore be more difficult because they have to make their decisions with less information. Participants also reported a poor sense of direction creates wayfinding problems. Peoples' internal awareness of their position and orientation is an important source of information, see Chapter 3. An absence of this information increases the uncertainty of wayfinding decisions. There were no age differences in the problems blamed on inattention or a poor sense of direction. Both elderly and young drivers had experienced problems as a consequence of them.

Another circumstance which caused wayfinding problems for drivers was inaccurate information. There were cases where the directional information they had been given was wrong. Inaccurate wayfinding information came from maps, road signs and the advice of others. The obvious problem of inaccurate wayfinding information is that it would lead to wrong decisions and conflict with accurate environmental information. For example, a non-elderly driver described a situation where he got lost because he was told to turn at a particular pub yet the pub's name had changed.

A final factor contributing to the uncertainty of wayfinding decisions relates to driver expectations. Expectations were also a source of inaccurate information. People can generate expectations about a journey from their driving experience and from their route plans. This problem was mainly expressed by elderly drivers and relates back to the phenomenon of schema described in Chapter 3. A spatial schema provides an understanding of the layout and pattern of typical environments and contributes to effective wayfinding in these environments (Blades, 1991) . Expectations are like anticipatory spatial schema (Mark & Frank, 1996; Neisser, 1976). Encountering something contrary to what was expected causes problems. For example, an elderly driver reported she had certain expectations about the appearance of her destination. She had trouble finding it because the building was in reality quite different to what she had envisaged.

Spatial schema may be very effective for wayfinding in an unfamiliar environment. This is particularly true in a city that has a predictable grid system layout, as was noted during the discussion of differences in nationality. However, the spatial schema in cognitive maps may be prone to create problems when encountering anomalies in the road environment. Things like road works, strange road geometry and inconsistent road labelling or numbering were frequent sources of wayfinding problems identified by discussants.

4.5.4. *Solutions*

A number of solutions to wayfinding problems were discussed in the focus groups. Most solutions proposed by the elderly drivers related to conventional changes to the road system, particularly changing signage. They blamed road signs most frequently for their navigation difficulties. The elderly drivers expressed a need for road signs which give more advanced warning, are larger (i.e., easier to read), more prominently positioned (i.e. above the roadway) and less cluttered. A need for better maintained signs was also mentioned. Lastly, elderly drivers wanted road signs to be placed after intersections to confirm their last manoeuvre (e.g., road number). This would help reduce some of the uncertainty caused by a lack of confidence.

Another method to assist elderly drivers might be to train them to modify their planning and wayfinding strategies to accommodate for specific age-related declines in their ability. Elderly drivers reported they did not change their strategies as they got older and there were no apparent differences with the strategies adopted by the non-elderly drivers. However, those strategies that served them well as young drivers may no longer be appropriate in old age. Elderly drivers could be made more aware of their limitations with respect to wayfinding. Making more thorough route plans and travelling with a passenger are two ways that could reduce some of their difficulties.

Reducing problems caused by inaccurate expectations would also eliminate some difficulties experienced while wayfinding. This could be done by reducing the occurrence of anomalies within the road system and encouraging its standardisation. For example, building address numbering could be standardised for size, sequencing and location. The English drivers who had experience of driving in North America seemed to have more positive reports of wayfinding. In some respects, this is consistent with reports that grid configurations facilitate geographic knowledge (Evans, et al., 1984).

Route Guidance Technology

New technology might also help elderly drivers with their wayfinding problems. This technology could provide them with more information that is more accessible. There are a number of considerations which need to be made prior to installing in-vehicle route guidance systems into cars. Given that route guidance systems were developed without due consideration to the needs of the user it is possible that they are not needed. If the systems are not needed then drivers will not want one, or if they have one they will not use it. The process of investing research into developing performance guidelines for in-vehicle route guidance systems would be a wasted effort if drivers will not adopt the technology. The following section will attempt to establish from the research literature that elderly drivers represent a potential user population and route guidance technology is a viable solution to wayfinding problems.

For elderly people, there is a widespread stereotype that they are resistant to new technology or have difficulty using new technology. If accurate there should be some concern about whether elderly drivers will adopt route guidance technology. Indeed, there is evidence to support this stereotype of elderly people resisting technological change (Zeithaml & Gilly, 1987). They are less likely than non-elderly people to own relatively recent technology like compact disc players or video recorders (Chappell, 1993) and use service tills (Al-Awar Smither, Braun, & Smither, 1991; Zeithaml & Gilly, 1987). Furthermore, Kerschner and Chelvsig (1981) found in a survey of consumers that elderly respondents have less positive views of new technology than non-elderly respondents.

There are a number of possible factors which influence elderly peoples' resistance to new technology. One factor is the image they perceive to be associated with the technology. Technology for elderly users should be non-stigmatising otherwise it will not be accepted (Charness, 1993). They have an aversion to anything that is associated with old age (Bowe, 1988). The rejection of route guidance systems on these grounds should not be of concern as long as they are not marketed specifically as an aid for elderly drivers.

Elderly people may also resist new technology as a result of their experience, particularly with computers. Elderly people have experienced lower rates of technological change in their youth, and as a consequence, have less aptitude for learning how to use new technology (La Buda, 1988). If this is indeed true, little can be done to influence their attitudes towards this new technology because it is dependent on experience. One possible strategy to enhance the appeal of route guidance systems might be to keep the systems simple, avoid complex functions and conceal the technology. This concern may decrease as the young people of today, who were raised on *high* technology, grow old.

Another factor influencing the acceptance of new technology by elderly users is its perceived usefulness. Elderly people are receptive to using new technology if they perceive it as being useful (Brickfield, 1984). This is consistent with theories of the acceptance of new technology by users in general. Davis (1993) found perceived usefulness of a particular technology is highly predictive of user acceptance. In fact, perceived usefulness is more predictive of the acceptance of new technology than its actual ease of use (Davis, 1993). Thus, designing a system to be perceived as being useful will have a greater impact on user acceptance than its actual usability. Nevertheless, these factors cannot be independent because a system that is impossible to use is not likely to be perceived as being useful.

Sixsmith (1990) conducted group discussions with elderly drivers about a variety of new in-vehicle technology systems. She found a mixture of positive and negative attitudes to the new technology. Some people were interested in the technology whereas others felt they were too old to have it in their lives. The less receptive drivers perceived that "...anything new in innovation is a little bit frightening..." p. 26. Sixsmith described her participants as being cautious in accepting new technology as progress. With respect to the route guidance systems, respondents had such negative comments as: they were too old for it, it was hazardous for elderly people, they would not trust it, they would not use it, they did not want it and it was too hard to learn. From this research it is clear that some elderly drivers are not receptive to route guidance technology.

Contrary to the findings of Sixsmith (1990), some studies report more favourable attitudes to route guidance systems. Wierwille (1990) reported elderly subjects had a preference for electronic route guidance maps over the traditional paper maps. Furthermore, elderly drivers accepted the navigation system at least as well as the non-elderly drivers. Participants in another study of elderly drivers using route guidance systems said they liked the system and it was useful in helping them to find their destination (Barham et al., 1993).

There are a number of explanations for the inconsistency in the receptivity of elderly drivers to route guidance technology found in the above studies. The inconsistency could be attributed to the type of participants used in the research. The Barham et al. (1993) study used members of a mature motorist guild who are not a representative sample of the overall population of elderly drivers. However, Sixsmith (1990) and Wierwille (1990) both used samples that were more representative of the population of elderly drivers.

The type of route guidance systems being assessed were more or less similar electronic moving map type displays: Wierwille (1990) used ETAK, Barham et al. (1993) used TravelPilot, and Sixsmith (1990) also looked at TravelPilot. Consequently, the type of route guidance technology may not be responsible for different findings among the three studies. Also, it should be noted that Sixsmith assessed the attitudes of elderly drivers towards two types of route guidance systems: TravelPilot and Autoguide, which provides guidance information with direction symbols and voice instructions. Subjects were reported to have preferred the Autoguide system.

Another explanation for the inconsistencies might be the different experimental methodologies employed in the studies. Both Barham et al. (1993) and Wierwille (1990) had their subjects using the systems while driving, whereas Sixsmith's (1990) subjects provided their opinions of the systems without actually having used them. The more receptive opinions may result from subjects having had applied experience with the systems.

Lastly, Wierwille (1990) and Barham et al. (1993) did not assess subjects' attitudes to route guidance technology in detail. These studies were more concerned with driving performance while using the systems and attitudes seemed more of an afterthought. Whereas, Sixsmith (1990) intended specifically to assess the attitudes of elderly drivers to in-vehicle technology. Perhaps Wierwille and Barham et al. would have found less receptive attitudes to the technology had they asked more direct questions.

In terms of the present study, elderly drivers generally expressed great interest in the technology if it was simple and non-distracting. Common concern with the route guidance system concept was it would be too distracting to use while driving, prohibitively expensive to buy, difficult to operate and difficult to program. Nevertheless, the elderly drivers believed an effective route guidance system would encourage them to be more adventurous. Nearly all discussants were aware of the concept of in-vehicle route guidance systems. This is different from Simms' (1993) who reported only three of the 45 English drivers aged over 70 interviewed were aware of route guidance technology. Sixty-two percent of Simms' respondents thought it would be useful.

Most participants preferred the concept of a route guidance system that gave verbal directions. Discussants believed instrument panel or head-up displays would be distracting and too difficult to use while in transit. However, from experience they liked to have maps to provide a visual overview of the route when necessary. Similar concerns were documented in research by Streeter et al. (1985).

If future in-vehicle route guidance systems are designed to match the needs of elderly drivers, and are perceived as being more useful, then it is more likely elderly drivers will be receptive to the technology. It is also possible that the negative appraisal of in-vehicle route guidance technology reported in some research may only apply to the current cohort of elderly drivers or poor system design. Thus, elderly drivers of the future may have a more positive appraisal of the systems. Issues relating to in-vehicle route guidance are discussed in more detail in Chapter 8.

4.6. Chapter Conclusions

This chapter reported the results of discussion groups with elderly and non-elderly drivers. Drivers discussed their wayfinding strategies and problems. The main problems were a lack of wayfinding information and inaccurate information. These were caused by features of the individual drivers and road environment. Elderly drivers tended to report more problems relating to a lack of information. This was mainly considered to be caused by inadequate signage and a lack of confidence. Problems relating to inaccurate wayfinding information did not exhibit any age differences. These problems were caused by false expectations (mainly due to anomalies in the road environment), and errors in maps, road signs and the advice of others. Solutions, from the discussion groups and theory, were to provide more information to drivers through improved signage. Route guidance technology may also be a potential solution to these problems.

This study was exploratory and the results are not conclusive. Further research is needed on a more representative sample of the driving population to support these findings. Nevertheless, the focus group discussions provided a qualitative awareness of the issues concerning elderly drivers and navigation. This gave useful insight and background for designing the survey described in chapter 5-7. Also, where available, evidence from previous research was generally consistent with the findings herein. The next chapter introduces research exploring these issues in greater depth and breadth.

Chapter 5: A Survey of Drivers
Introduction and Method

5.1. Chapter Summary

This chapter provides the rationale for conducting a postal questionnaire survey of drivers. It is based on the information gathered during the focus groups discussions described in Chapter 4. Research methodology is reviewed and issues in research on ageing are discussed. The second half of the chapter describes the survey methodology and content of the questionnaire. For the methodology, details are given about the database, respondents, ethical considerations, survey procedure and analysis. The survey results are presented in Chapter 6 and discussed in Chapter 7.*

5.2. Introduction

Some wayfinding problems and information needs of elderly drivers were identified in the focus group discussions described in Chapter 4. It was concluded that more evidence was needed to better establish the nature and extent of these problems. To this end, additional research on driver route planning and wayfinding strategies was required. A more detailed account of the causes and consequences of wayfinding problems was also needed.

Elderly drivers have been the topic of much research and various methods have been employed to investigate the effects of ageing on driving. The relationship between old age and driving behaviour has been explored using laboratory measures (e.g., Owsley & Ball, 1993), experiments in

*This is based on research presented at the *13th Triennial Congress of International Ergonomics Association* (Burns, 1997) and the *International Conference on Traffic and Transport Psychology* (Burns, 1996). This research is also under review for publication in the *Journal of Environmental Psychology* and *The Journals of Gerontology: Social Sciences.*

driving simulators (e.g., Brouwer et al., 1991), field studies (e.g., Wierwille, 1990), archival data (e.g., Hakamies-Blomqvist, 1993; Jette & Branch, 1992), surveys and interviews (e.g., Fildes & Lee, 1994; Rothe et al., 1990).

A broad array of methods have also been used to research the route planning and wayfinding of drivers. There have been laboratory measures (e.g., Jackson, 1996), experiments in driving simulators (e.g., Pauzie & Anadon, 1993), field studies (e.g., Streeter et al., 1985), and surveys (e.g., Streff & Wallace, 1993). Beyond the focus group discussions in Chapter 4, no research has been found that looks specifically at conventional route planning and wayfinding among elderly drivers.

The use of surveys is the most common approach reported in the literature to investigating the problems of elderly drivers. These surveys use different methods to answer a range of research questions. The first part of this chapter reviews the research methodology in this field. The results of the surveys listed below were discussed in Chapter 2.

Carp (1971, 1980) used interviews in the homes of 709 retired people in San Antonio Texas and 899 retired people in San Francisco. These studies investigated the implications driving problems have for personal fulfilment and social contribution. Participants were aged 50 to 85 (82% were over 65 years of age). No specific details were given in either report about the interviews or how the respondents were recruited.

Yee (1985) carried out a survey of 446 elderly American drivers (55+ years) and 106 younger drivers (30-45 years) as a comparison sample. Yee was interested in which retired people drove or did not drive; where and how often they drove; problems they had and the implications these problems had for mobility; and causes of these problems. The respondents were members of a motoring organisation. No response rate was cited. The survey focused on mobility and safety needs using a 42 page postal questionnaire.

The AA Foundation for Road Safety Research (1988) conducted a self-report survey of 996 U.K. motorists over the age of 55. It explored the problems faced by elderly drivers, their driving behaviour, health and coping strategies. The survey was conducted by a market research company who distributed self-report questionnaires to personally recruited individuals at sampling points around the country. Respondents took up to three hours to complete the questionnaire. The response rate was cited as being almost 93%. A quota was set to interview a sample of drivers approximating known sex and age profiles of elderly drivers from unspecified published statistics.

Rothe et al. (1990) conducted interviews with 904 elderly Canadian drivers (55+ years). The content of the survey was based on focus group discussions and research literature. It consisted of 61 questions divided into 10 sections: demographics, driving history, vehicle driven, driving patterns, opinions, difficulties, licensing, driving education, changes over time, and difficult driving manoeuvres. Participants were recruited through radio and newspaper announcements, random dialling and notices in seniors' centres. The structured interview lasted between 45 and 75 minutes and was conducted at a time and place convenient to the respondent (usually at their own home).

Bishu, Foster, and McCoy (1991) conducted a postal questionnaire survey of elderly American drivers (65+ years). They were interested in defining the problems of elderly drivers. The survey contained 78 questions on demography, driving history, driving manoeuvres, health and attitudes about safety. The survey was posted to 770 elderly licence holders and had 425 questionnaires returned; giving them a 55% response rate.

Simms (1993) surveyed 356 English driving licence holders over 70 years of age. She asked questions about health, past driving experience, mileage and car use. Recruitment involved a contact letter being sent to 500 people inviting them to participate in an face-to-face interview. Twenty-nine specially trained interviewers visited the 356 respondents in their homes (71% response rate).

The Ministry of Transportation Ontario (MTO, 1994) conducted a pilot survey of elderly drivers aged 50-79 years. They were interested in developing an inventory to measure: the perception/awareness of driving abilities, deficits, and personal risk; self-restriction of driving and other compensatory behaviours; and denial of deficits. The initial intention was to interview 100 licensed drivers. To this end, they selected a random sample of 252 elderly licence holders living in and around Peterborough, Ontario. The drivers were contacted by phone and asked to participate in the study. Response rate was low (21%) so the researchers decided to mail a questionnaire to an additional 260 elderly drivers. They managed to collect 167 responses in total (33% response rate).

Rabbitt et al. (1996) conducted a postal survey of elderly U.K. driver licence holders (55+ years). They were specifically interested in why elderly drivers give up driving. Respondents were recruited from media appeals and a database of research volunteers. Two questionnaires with a covering letter were sent to a total of 2700 contacts. One asked about their past experience and future expectations of driving. The second questionnaire was used to measure details of previous and current health problems. There were 2134 completed questionnaires representing a response rate of 79%.

Chapter 3 described some of the survey research on driver route planning and wayfinding (e.g., Streff & Wallace, 1993). The next section discusses the key methodological issues involved in conducting survey research and research on the elderly.

5.2.1. *Methodological Issues*

Surveys

There are three main methodological issues in survey research: coverage, method of data collection, and method of analysis and interpretation (Moser & Kalton, 1971). Consideration of survey objectives and available resources guide decisions about methodology. With respect to coverage, this research was interested in navigation amongst drivers, particularly elderly drivers.

Research proposals were sent to some motoring organisations to enquire if they would provide access to their database of drivers. A database of drivers' names, ages and addresses was required for the survey. One motoring organisation agreed to co-operate with this project.

There are three major survey research methods: postal questionnaire, personal interview, and telephone survey (Frankfort-Nachmias & Nachmais, 1992). The advantage with postal questionnaires is they are low cost, avoid interviewer biasing errors, can be anonymous and provide good accessibility to respondents. Postal questionnaires also provide an opportunity for respondents to take their time to consider responses. The disadvantages of this technique are potentially low response rates and the inability to query or probe responses.

The advantages of conducting interview surveys, by telephone or in person, are they are flexible and allow the interviewer to clarify questions and probe responses (Frankfort-Nachmias & Nachmais, 1992). Interviews also offer greater control over the sequence of questions and usually have high response rates. The main disadvantages of these survey methods are the lack of anonymity and risk of interviewer bias in responses. Interviews may also be more expensive than postal surveys.

For the purposes of this research, it was decided a postal questionnaire survey would be the most appropriate method. In order to get an accurate and representative account of wayfinding behaviour, a large number of respondents was needed. A large sample was also needed to provide the statistical power to determine the size and significance of the relationship between mobility and wayfinding problems within a large set of intervening variables. Furthermore, interviews of a large sample of drivers, in person or by telephone, exceeded the resources available.

A primary concern of data collection with postal questionnaire surveys is the response rate. It is important to have a high survey response rate because it avoids the problems of non-response biases (Jobber & Saunders, 1989). This bias occurs when survey results are affected by a difference between respondents and non-respondents. A low response rate threatens generalisability of the survey results to the population from which the sample was selected. In order to reduce this problem, steps were taken to maximise the number of respondents.

Jobber (1990) and Frankfort-Nachmias and Nachmais (1992) review the research on postal survey response rates. They identify how various features of survey and questionnaire design influence the return. The following features have been shown to improve response to postal surveys: monetary and non-monetary incentives, follow-up letters with questionnaires, stamped return envelopes, deadlines, anonymity, closed response format questions and questionnaires of shorter length. Also, a covering letter with an altruistic appeal (help us) is more effective than one with an egoistic appeal (what you say is important). All of these features were considered in the design of the questionnaire and survey procedure.

A problem with self-report data is respondents may not be entirely aware of their limitations (e.g., Moser & Kalton, 1971). They may not be qualified to make judgements about their abilities because they lack the knowledge. This was not a great concern here because respondents were asked to make fairly simple self-assessments. For example, *how do you plan your routes.* They were not asked to make difficult assessments like evaluating their cognitive functioning. It was also hoped that relating questions to specific driving situations would help them to assess their performance well.

A similar concern is respondents may not want to answer correctly. For example, a person may consciously or subconsciously wish to deny any personal difficulties with driving. Carp (1971), using projective tests in interviews with elderly drivers, found there existed a defensive denial of driving problems that provoked considerable negative emotion. Although this problem may be unavoidable, little trouble was expected since previous research has shown many elderly drivers readily acknowledge their limitations (e.g., Sixsmith, 1990 and Chapter 4).

Psychological and Cognitive Ageing Research

Some of the methodological problems associated with research on ageing have been described by Schaie (1988). These problems include: confounding ageing with disease processes or cohort differences, treating the elderly as a single population rather than subgroups like *young-old* and *old-old,* and assuming statistically significant age differences are meaningful differences. The inability to distinguish between normal age changes and disease was a concern for this research. An effort was made to minimise this problem by asking respondents to provide health ratings. These ratings were considered in analyses where age was used as predictor. This would help to eliminate variation caused by disease rather than normal ageing.

Another issue in research on ageing is the power to distinguish age effects from cohort effects. The use of age-comparative data collected at one point in time risks confounding with generational or cohort differences (Schaie, 1988). An age cohort refers to a group of people born during a given time period who share the same historic environment and many of the same life experiences at the same age (Meredith & Schewe, 1994). These common experiences can lead to special characteristics. "Many age differences that are reported in the literature, instead of being *caused* by aging, are more likely to be attributable to differences in demographic characteristics and cohort specific experiences than to adverse maturation changes" (Schaie, 1988, p. 180). This is a particular concern when investigating driving behaviour.

This survey had to use a cross-sectional design. The time span of a doctoral research project would make it difficult to carry out longitudinal survey research on drivers as they age. Caution would have to be exercised when defining age/cohort boundaries and interpreting the results of this research. The potential impact of cohort differences would have to be considered when examining any apparent age effects. Age differences that could be explained by cohort effects will be identified.

The magnitude of age differences is also an important issue when interpreting results. Although research may detect small and consistently reliable age differences, these findings may "...remain irrelevant to social policy decisions when the age change does not lower performance beyond critical threshold values for adequate performance of a criterion task or social role" (Schaie, 1988, p. 181). The nature of the research herein makes this issue less of a concern. The performance and information needs of elderly drivers were being assessed for the purpose of reducing problems. It is not the intention of this research to influence driver licensing policies. Nevertheless, as a matter of good statistical practice, the magnitude of results (i.e., effect sizes) would be considered in this research.

Wayfinding Performance

The hypothesised or proven factors that affect wayfinding performance were described in Chapter 3 (Section 3.7). These factors were categorised as being environmental or individual. Figure 3.3 listed all the individual factors that are believed to affect wayfinding performance. Some of these factors are difficult to measure or cannot be measured with a postal questionnaire. Driver *rate of decision making* and *memory* could not be measured by a self-administered questionnaire, they require laboratory based measurement techniques. *Personality* can be measured by questionnaire (e.g., DeJoy (1989) but a personality inventory would increase the size of the questionnaire. A long questionnaire has to be avoided because it would lower the response rate.

The model of the individual factors influencing wayfinding performance (Figure 3.3) was adapted to exclude these factors that could not be measured in a questionnaire. This model appears in Figure 5.1. The interrelationships among the variables and wayfinding performance are indicated with arrows. The direction of these relationships are also shown. This is a fully recursive path model so the predicted relationships are unidirectional. *Age* is predicted to have a direct effect on *wayfinding performance*. It is also believed to affect *wayfinding performance* indirectly through *vision, health, spatial ability* and *experience*. *Gender* also affects *wayfinding performance* indirectly through *spatial ability, experience* and *confidence*.

In Chapter 3 (Section 3.7.2), the *strategies* drivers use to find their way were also predicted to have a differential impact on wayfinding performance. Although navigation strategies will be measured in the questionnaire, they are not included in this model because strategies can only be described categorically and the planned path analysis of this model demands continuous variables. Despite the removal of some of the proposed predictors of wayfinding performance, it is believed this model will reliably account for many of the important factors that cause individual variations in wayfinding performance.

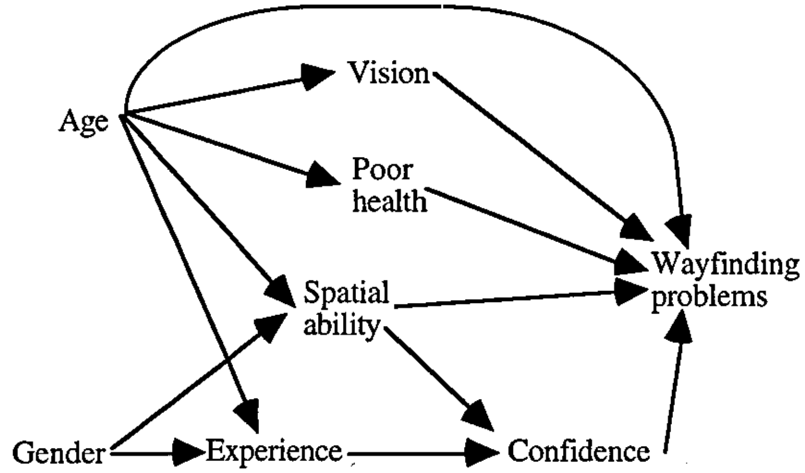


Figure 5.1. Selected individual influences on wayfinding performance.

5.3. Method

5.3.1. *Aims of the Survey*

The aims of this survey were to identify how drivers plan their routes and identify their wayfinding strategies. The study also sought to measure the prevalence of navigation problems amongst the driving population, particularly elderly drivers. Lastly, it aimed to determine the types of navigation problems drivers encounter, as well as their causes, consequences and psychological implications.

5.3.1. *Sampling*

A stratified sample of 2000 licensed drivers across the United Kingdom was requested from a motoring organisation's direct marketing system. The direct marketing system contains the names, addresses and other details of people who have contacted the organisation or an affiliated business. Half of the sample (1000) were members of the motoring organisation. Half of the sample (1000) were under 60 years of age and half were 60 years and over. Since this research was interested in the mechanism of wayfinding among elderly drivers, a sample was selected that over-represented the proportion of elderly people in the driving population. Drivers of all ages had to be sampled in order to distinguish issues specific to the elderly.

5.3.2. *Ethical Considerations*

The survey was undertaken in accordance with the Loughborough University Department of Human Sciences ethics guidelines and Marketing Research Code of Conduct. It was also in compliance with the Data Protection Act. Responses were confidential and respondents' anonymity was guaranteed. No names were indicated on the completed questionnaire and results of the research could not be traced to any individual respondent. It was considered unlikely that the nature of the questions in the survey would adversely affect respondents. No other persons had access to the completed questionnaires.

5.3.3. *Respondents*

The total number of respondents was 1184 from the 1950 questionnaires sent out. Seventy responses were considered invalid because the addressee had moved, died or stopped driving. Thus the response rate was calculated from a total 1880 potential respondents. This gave a response rate of 63%. The motoring organisation generally expects to get a response rate of 55% with their surveys drawn from the same database (see Appendix B for response rate analysis). The initial posting had a 53% response rate and the reminder encouraged another 10%.

Respondents' ages ranged from 21 to 85 with a mean age of 55 (SD = 16.8). There were 574 (48.7%) drivers under 60 and 604 (51.3%) over 60. The mean age for the males was 56.8 years (SD = 16.4) and it was 50.4 years (SD = 16.9) for the females. There were 851 (71.9%) male respondents and 333 (28.1%) females. In 1991, 39.8 % of all licensed drivers in the U.K. were female (DoT, 1993). In that same year, 33% of 60 to 69 year old females and 15% of those 70 and over held drivers licences. For men these values were 78% and 58%. Therefore, although the number of female respondents was low, it was close to the actual proportions in the population.

It should be noted that the respondents in this survey may not be entirely representative of the population of U.K. motorists because they were selected from a motoring organisation's marketing system. A random selection from a database of all licensed drivers in the U.K. would have been ideal.

5.3.4. *Questionnaire*

The questionnaire had 160 questions and took approximately 20 minutes to complete during pilot testing, see Appendix C. There were nine sides of A4 printed on both sides. The questionnaire was designed from information gathered during focus group discussions with drivers (See Chapter 4), from the literature and pilot testing (See Section 5.3.6). It was divided into four sections labelled: *driving experience, planning routes, finding your way while driving,* and *additional information*. The questionnaire ended with a general open-ended question about how to make wayfinding safer. The remainder of this section describes its contents.

Driving Experience

The first section of the questionnaire sought to determine information about peoples' mobility, the restrictions to their driving and driving experience. There were 20 questions in this section and some had sub-questions. For mobility, questions were asked about their mileage, amount of driving on unfamiliar routes, driving activities, the importance of driving, independence and transportation alternatives.

For restrictions to mobility, questions were designed to measure respondents' access to cars, the impact costs had on their driving, and causes of reductions in their driving. Questions were also included to identify the situations they avoided, changes to their driving habits and factors which had recently caused them to change their driving.

Questions about when they had obtained their driver's licence, and how long respondents had been driving regularly, were included to indicate their driving experience.

Route Planning

This section contained three main questions on route planning. The first question (No. 21 in Appendix C) asked respondents to describe their route planning strategies in advance of travelling on unfamiliar trips. The type of route was divided into four different categories: motorway, major road, minor road and unfamiliar city. There were eight pre-coded options provided (e.g., *made notes of the route*). These options were derived from strategies identified in the discussion groups, pilot testing or literature (e.g., Mark & McGranaghan, 1988). Respondents were instructed to record more than one strategy. There was also space provided for *other* strategies which had not been listed.

The second question (No. 22) interrogated respondents about the level of difficulty of five different route planning strategies (e.g., *making notes to plan a route*). These strategies were taken from the options listed in the previous question. Responses were indicated on a 5-point scale ranging from *very difficult* to *very easy*. A *do not know* option was also provided for each of these questions. The final question (No. 23) in this section asked respondents how they could improve their route planning strategy.

Wayfinding

The section on wayfinding was the largest in the questionnaire. There were 54 questions including the sub-questions. They asked about map usage, road signs, information and wayfinding abilities, problems, errors and strategies.

The first questions in this section asked if they kept maps in their car and whether or not they would refer to these maps while driving. Another question determined if respondents preferred to drive, travel as a passenger or had no preference.

A set of six questions (No. 31) were designed to determine how people rated their ability to perform specific wayfinding tasks. They were asked to indicate their ability at: *finding your way to an unfamiliar place, reading maps, distinguishing between right and left hand directions, telling which direction is north, seeing what road signs say,* and *reading road signs while your car is moving.* Answers were indicated on a 5-point scale ranging from *very good* to *very poor.*

One question (No. 32) asked respondents to describe how they *find their way while driving.* The format was similar to the route planning question in the previous section. The type of route was divided into four different categories: motorway, major road, minor road and unfamiliar city. Seven pre-coded response options were provided (e.g., *read a street map*). Respondents were permitted to indicate up to four strategies from each road type or *other* strategies not listed.

In the next question (No. 33) respondents rated their perceived difficulty of wayfinding on motorways, major roads, minor roads, in cities, and to a particular destination. Answers were indicated on a 5-point scale ranging from *very difficult* to *very easy.*

In order to understand the implications of wayfinding problems, they were asked *how do you feel when you get lost while driving.* Responses to this question were indicated across 14 mood adjectives, seven positive and seven negative. Examples of the negative adjectives are *irritated, anxious* and *foolish*. The positive adjectives included *comfortable, safe* and *confident*. Respondents were able to give up to five answers for this question.

Another set of questions (No. 35) asked respondents to indicate the frequency with which they had experienced 16 problems related to wayfinding (e.g., *missed a road sign* and *turned in the wrong direction*) Answers were indicated on a 5-point scale ranging from *never* to *always*. These 16 pre-coded problems were derived from the most frequent errors reported by drivers during focus group discussions and from a study evaluating navigational aids (Streeter et al., 1985).

Questions (No. 37-39) were also included in the questionnaire to measure spatial ability without specific reference to wayfinding. Drivers were asked, for example; *how would you describe your sense of direction*. A 5-point scale ranging from *very good* to *very poor* was used for responses. Research has shown that people are aware of their sense of direction and these self-report accounts relate to their ability to orient themselves (Bryant, 1982; Kozlowski & Bryant, 1977). Another question asked respondents how often they experienced the situation *I have trouble remembering where I parked my car*. A 5-point scale ranging from *always* to *never* was used to indicate responses.

Questions also sought to determine driver information needs while wayfinding. Respondents were asked to indicate the type of route information they found useful while driving on a motorway or in a city. The pre-coded responses for the city question were: *landmarks, road numbers, street names, distances, lane position, left-right directions, road layout* and *compass directions*. The pre-coded responses for the motorway/dual carriageway question were: *landmarks, road numbers, road layout, compass directions, place names, left-right directions, distances* and *junction numbers*. Another question asked respondents to indicate which information for identifying a turn would they want from a passenger. There were eight pre-coded responses for this question: *landmark, far distance (e.g., 2 miles), near distance (e.g., 200 yards), street name, a road number to follow, left-right directions, road layout* and *compass directions*. All three of these questions had space provided for *other* types of information that had not been listed. Respondents were able to make three choices for each question.

Two open-ended questions appeared in this section: *Are there any changes that you would make to improve road signs?* and *Can you identify any things that have caused you to lose your way while driving?* Respondents were permitted up to three responses for each of these questions.

A series of questions about fitness (No. 40) were also included in the wayfinding section of the questionnaire. These questions sought to identify problems with vision, flexibility, fatigue and general health that might have an impact on driving and wayfinding performance. Answers were indicated on a 5-point scale ranging from *always* to *never* .

Personal and Household Characteristics

The final section of the questionnaire served to collect additional demographic information. The drivers were asked to indicate their gender, age, employment status, residential setting and the number of years they had lived there. This last question was asked in order to get an impression of how familiar they might have been with the area in which they lived. Two more questions about general health were also included in this section.

Questions about education, marital status and income were excluded because they were considered unnecessary and intrusive. There was a concern that intrusive questions would adversely affect response rates. Specific questions were designed to assess driving freedom. The impact education, marital status and income have on mobility involves being able to afford to drive, having access to a car, residential setting, transportation alternatives and need to drive. These questions relating to more direct moderators of mobility were placed in preceding sections of the questionnaire.

5.3.5. *Survey Materials*

The survey package had a covering letter (See Appendix D), questionnaire, address label, reply envelope with freepost label, and a ball point pen. Two thousand of these packs were sent out. The reminder package included another covering letter (See Appendix D) and questionnaire. There were 970 reminder packs sent out.

5.3.6. *Survey Procedure*

Pilot Survey

A formal run of the survey procedure was conducted with 50 drivers whose names and addresses were drawn pseudo randomly from the list provided by the motoring organisation. This procedure is described in the next section. Nineteen drivers responded to the pilot survey giving a response rate of 38%. The procedure was identical to that of the main survey except no reminder was posted.

The questionnaire was revised after the pilot survey. The revised version appears in Appendix C and was described earlier in Section 5.3.4. Changes were made to questions that had confused or mislead respondents. The explanations which accompanied some questions were clarified and a few questions were removed from the survey. Some of the pre-coded response options were also removed because no pilot respondents had selected them. The revised questionnaire was tested on a sample of colleagues to ensure the changes were appropriate. It was one side shorter than the original ten pages. Changes were also made to the covering letter. It was predicted that these changes, and a reminder, would increase the response rate to a more acceptable level.

Main Survey

The covering letter were addressed anonymously to *Dear Sir/Madam* (See Appendix D). It was believed the anonymity of the letter would be consistent with the anonymity of their reply to the questionnaire. They were given a two week deadline to complete the questionnaire. A ball point pen was included with the questionnaires as an incentive to respond. Freepost return envelopes were provided with the questionnaire package to facilitate replies.

There were 2 sets of the 1950 address labels. Each address was linked to a questionnaire by a number. This was done to avoid sending out unnecessary reminders. When a questionnaire was returned the second address of the respondent was destroyed. Reminders were sent using the remaining address labels.

Reminder packages were sent three weeks after the initial posting to drivers who had not replied. A questionnaire was sent with the reminder in case they had misplaced the original. Individual numbers were not used to identify these second questionnaires. No deadline was given in the reminder letter and there was no closing date to accepting the completed questionnaires. Most of the returned questionnaires came within two weeks of the reminder. Only a few questionnaires were received later.

5.3.7. *Treatment of Data*

Compilation of Data

Data from the questionnaires were manually entered into a single computer file using a spreadsheet program. The open-ended questions were coded as each different answer was encountered. Although this led to 55 different codes for one question, no information was lost and these codes could be collapsed into more general response categories later if required. Some of the open-ended questions enabled people to provide multiple responses. Space was provided in the database to accommodate extra responses. Data were screened for encoding errors and compiled using SPSS (Statistical Package for the Social Sciences). Descriptive and inferential statistical analyses were conducted. These are described in Chapter 6.

5.4. Chapter Conclusions

This chapter reviewed some of the research methods employed to investigate elderly drivers or navigation. It was decided a postal questionnaire survey would be the most suitable approach to investigating the research questions. A survey provided an opportunity to record the navigation behaviour of a large and representative sample of motorists. It was believed that these advantages exceeded the methodological concerns about the risk of low response rates and using cross-sectional data to investigate the effects of ageing.

A model of the individual factors that influence wayfinding performance was adjusted to fit information that could be collected by questionnaire. The questionnaire was developed from information gathered during the focus groups discussions with drivers, from the literature and several stages of pilot testing. A formal pilot survey of the questionnaire lead to some final modifications before the main survey was posted. The survey response rate and the distribution of respondents across gender and age were considered to be acceptable. Results of the survey are presented in Chapter 6.

Chapter 6: Survey Results

6.1. Chapter Summary

This chapter describes the results of the questionnaire survey of drivers. Analyses centre around different sections of the questionnaire. Results are discussed concerning respondent demographics, driving activities and access to cars. Information on number and frequency of familiar and unfamiliar trips is also presented. Situations that drivers avoid are described. Route planning and wayfinding strategies are investigated. Wayfinding information needs and problems in different driving situations are also described. Lastly, the causes and implications of wayfinding problems are presented. Analyses look at both gender and age differences. A detailed discussion of these results appears in Chapter 7.

6.2. Demographics

A series of questions asked for respondent demographic information. Sixty-four percent of drivers < 60 years of age and 9% of those 60 years were employed full-time (N = 1171). Twelve percent of drivers < 60 and 7% of those 60 were employed part-time. Seventy-eight percent of respondents 60 were retired. Eighty-seven percent of drivers < 60 and 18% of those 60 were working in some capacity; not working included retirement, housewives/ husbands, students, and those on sick leave. The number of respondents for this question did not amount to the survey total of 1184. This was because 13 questionnaires had missing values for either the age or employment question. In terms of the percentage of respondents by residential setting, most lived in towns or suburban areas (58%). There were 13% of respondents who lived in cities, 16% in villages, and 12% in rural areas. There were no age differences in terms of residential setting.

Non-elderly drivers rated themselves to have better than *average* health for the self-reported ratings of present health. In an analysis of variance, there was a significant main effect for age [$F(5, 1159) = 15.26$, $p < 0.0001$, $\eta^2 = 0.06$], such that mean elderly ratings were worse than non-elderly drivers on a 5-point scale ranging from *very poor* to *very good*. The critical value for statistical significance is set at $\alpha = 0.01$ for all analyses reported in this chapter. The use of this conservative level of significance was motivated by the large sample size. Eta squared (η^2) is a measure of the strength of association (Keppel & Zedeck, 1989; Tabachnick & Fidell, 1989). It represents the percentage of total criterion (Y) variability that is explained by the predictor (X) variable. In this case, six percent of self-reported health ratings can be predicted by age.

There were no significant differences across ages groups, or gender, in the frequency with which health prevented respondents from driving. Health rarely if ever prevented respondents from driving. Similarly, there were no significant differences across ages groups, or gender, in the frequency with which respondents exercised.

Sixty-five percent of respondents (n = 767) had not changed their driving habits within the last five years. Drivers who had changed their driving were asked to describe how. Ninety-one percent of them gave a response to this open-ended question. Responses were coded into three general categories: drive less (28%), drive more (12%) and other (60%). There were 20 different other responses. The five most common other responses were: more careful or cautious (20%), retirement (12%), changed work (7%), no longer drive to work (3%) and more confidence (3%). Of the respondents who drive less, 66% were elderly (60 years of age), and 16% of those who drive more were elderly.

Respondents were asked to indicate how long they had been living in their area. Most respondents had been living in the same area for over five years (86%), and 70% had been living in the same area for over 10 years. For elderly drivers, 95% had lived in the same area for over 5 years. Only 23% of non-elderly respondents and 5% of elderly respondents had lived in the same area for less than five years.

6.3. Driving Activities

The age at which respondents had got their driver's licence ranged from 15 to 60 years (see Figure 6.1). The mean age at which drivers first got their licence for all respondents was 24.2 years (SD = 8.9). When considering gender, the mean age for females was 26.7 years (SD = 8.0) and 23.3 years (SD = 8.0) for males. The non-elderly drivers (< 60 years of age) got their licence at the mean age of 21 years (SD = 5.9) and elderly drivers (60 years of age) got theirs at 27 years (SD = 10.2). There is an increase in the age at which drivers first got their licence across age groups such that non-elderly drivers tended to get licenced at an earlier age [$F(5, 1125) = 54.59, p < 0.0001, \eta^2 = 0.18$]. The same pattern can be observed between male and female drivers, yet women tend to get licences at an older age than males [$F(1, 1125) = 85.64, p < 0.0001, \eta^2 = 0.06$]. However there is a significant interaction, such that this difference between male and female drivers is less amongst younger generations [$F(5, 1125) = 8.81, p < 0.0001, \eta^2 = 0.03$]. This analysis was based on a skewed distribution of the licence age variable. The same results, in terms of significance levels, apply when the variable is transformed (square root) to a more normal distribution.

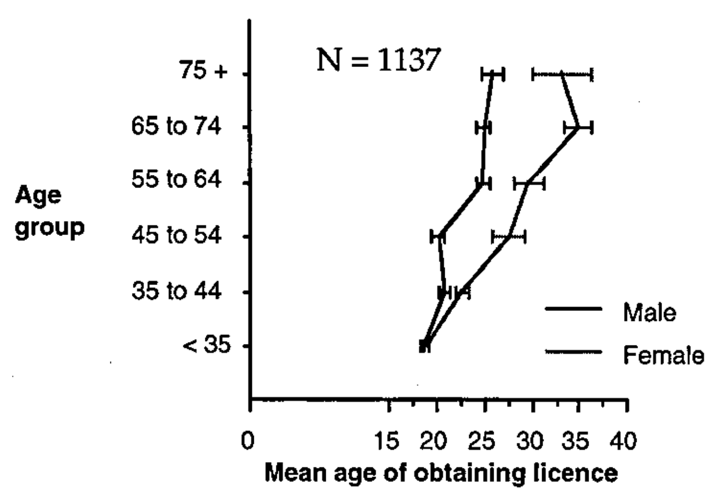


Figure 6.1 Mean age when drivers licenced, by age group and gender (± 1 standard error).

The bars plotted in Figure 6.1 represent the standard error of the mean. This describes the interval around the sample mean which is expected to contain the population mean.

Another question was included to assess driving experience. This asked respondents how long they had been driving regularly. Regularly was defined as being more than once a week. The mean driving experience rating for all respondents was 29 years (SD = 15.4). When looking at gender, the mean for females was 22 years (SD = 13.7) and 32 years (SD = 15.1) for males. Figure 6.2 shows the difference in driving experience between males and females [$F(1, 1149) = 84.29, p < 0.0001, \eta^2 = 0.02$] and the clear trend of increasing experience with age [$F(5, 1149) = 352.43, p < 0.0001, \eta^2 = 0.58$]. There is also an interaction between gender and age where the experience gap between males and females tends to increase across age group [$F(5, 1149) = 10.90, p < 0.0001, \eta^2 = 0.03$]. This is consistent with Figure 6.1 that plots licensing age.

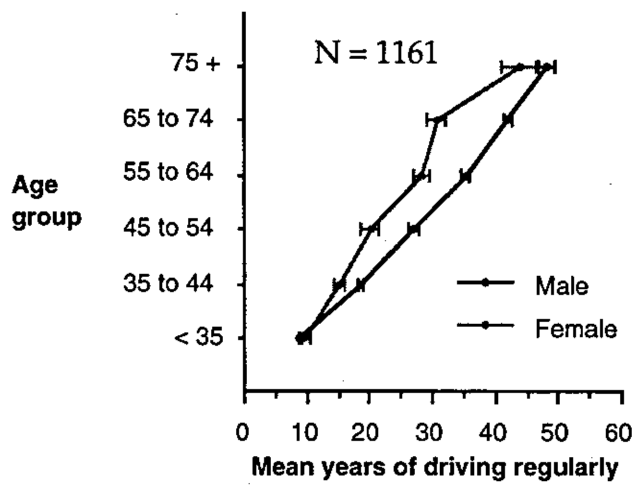


Figure 6.2. Mean number of years of driving regularly, by age group and gender (± 1 standard error).

The respondents were asked to indicate their most common method of travelling locally. There were no significant differences in the pattern of responses for age or gender. The most common method of getting about locally, in a descending order of popularity, were to drive (77%), walk (18%), bicycle (3%), and bus (2%). Only five respondents said they would get a lift from an acquaintance and no one reported that they use taxis.

There were differences in the distribution of responses by both gender (see Figure 6.3a) and age group (see Figure 6.3b) in the method they use to travel long distances (> 30 miles). More female respondents travel long distances in cars as passengers than males. More elderly respondents (60 years of age) travel by coach than younger generations of respondents (> 60 years of age) .

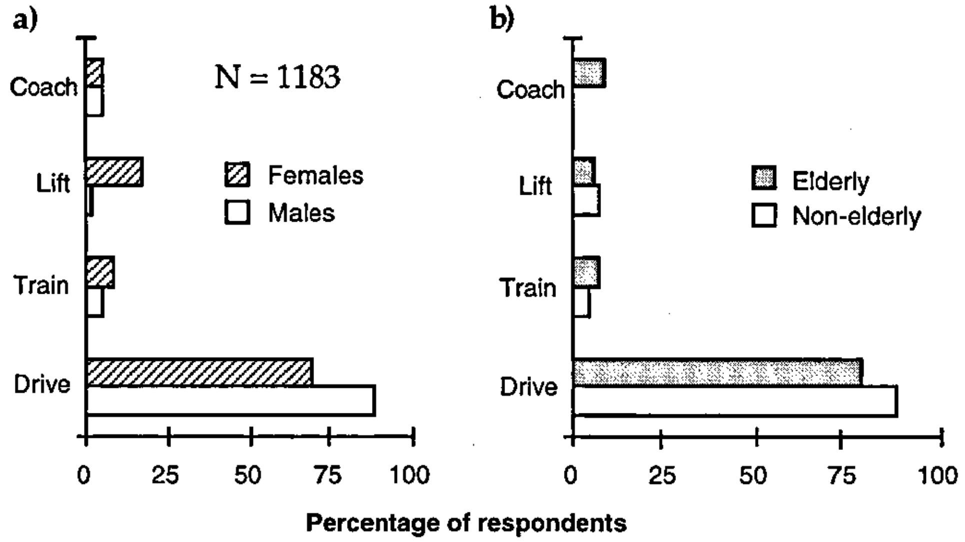


Figure 6.3a & b. Methods of travelling long distances (> 30 miles).

The respondents were asked to indicate how they preferred to travel by car: as a driver (61%), passenger (10%), or no preference (29%). This pattern of responses was similar across age groups. However, there was a difference between male and female drivers' answers to this question (see Figure 6.4). More male respondents preferred to drive when travelling by car than females, whereas more than half the female respondents had either no preference or would rather travel as a passenger.

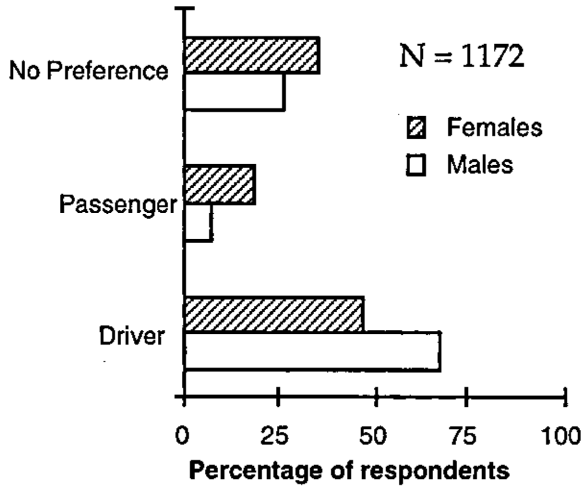


Figure 6.4. Driving preferences, by gender.

Respondents were asked to provide a rationale for their response to this question. Reasons given for preferring to be the driver were: feel safer, confident, or desire to be in control; obligation; enjoy driving or find it easier; and suffer motion sickness as passenger. Reasons given for preferring to be a passenger were: less stressful, more relaxing and easier; do not enjoy driving; lack confidence or rely on a better driver; can enjoy passing scenery; and to help navigate. A common reason given for a no preference response was that it depended on the driving situation or their trust in the driver.

Driving was considered to be important by the vast majority of respondents. Ninety-one percent of drivers rated driving as being at least *very important*. Less than 3% of drivers rated it as not being important.

6.3.1. *Access to Cars*

In order to identify possible restrictions to driving, respondents were asked to indicate how often they had a car available for driving. Nearly all respondents always had a car available. There were only 15 people who did not always have access to a car and these drivers had a car available *most days*.

Respondents were asked if they would like to change the amount of driving they do: 67% of respondents did not want to change the amount they drive, 21% wanted to drive less, 2% never, and 10% wanted to drive more. There were significant gender [$F(1, 1159) = 11.23, p < 0.001, \eta^2 = 0.01$] and age differences [$F(5, 1159) = 4.21, p < 0.001, \eta^2 = 0.01$], such that males and non-elderly respondents preferred to drive less, and female and older drivers did not want to change the amount they drove.

The cost of driving may also have an impact on the amount of driving people do. Respondents were asked to report how much the cost of running their car influenced the amount they drove. Seventy-two percent said cost had no impact on their amount of driving, 23% said it decreases the amount they drive and 5% said it increases their driving. There were no gender differences but the costs of driving had an impact on the amount elderly respondents drove [$F(5, 1168) = 3.90, p < 0.005, \eta^2 = 0.02$]. Eighteen percent of non-elderly drivers (< 60) and 28% of elderly drivers (

60) reported costs had a negative influence on the amount of driving they did.

6.3.2. *Trip Purpose*

Respondents were asked to identify *the three most important activities they need their car for* (see Figure 6.5). These percentages were based on multiple frequencies calculated on a maximum three responses per person. The values represent the percentage of people within the age group who reported that activity. For example, 93.1% of young respondents and 29.3% of elderly respondents listed work as one of their most important driving activities. Figure 6.6 shows 272% of responses. On average, this suggests people provided slightly less than three responses (M = 2.72 responses).

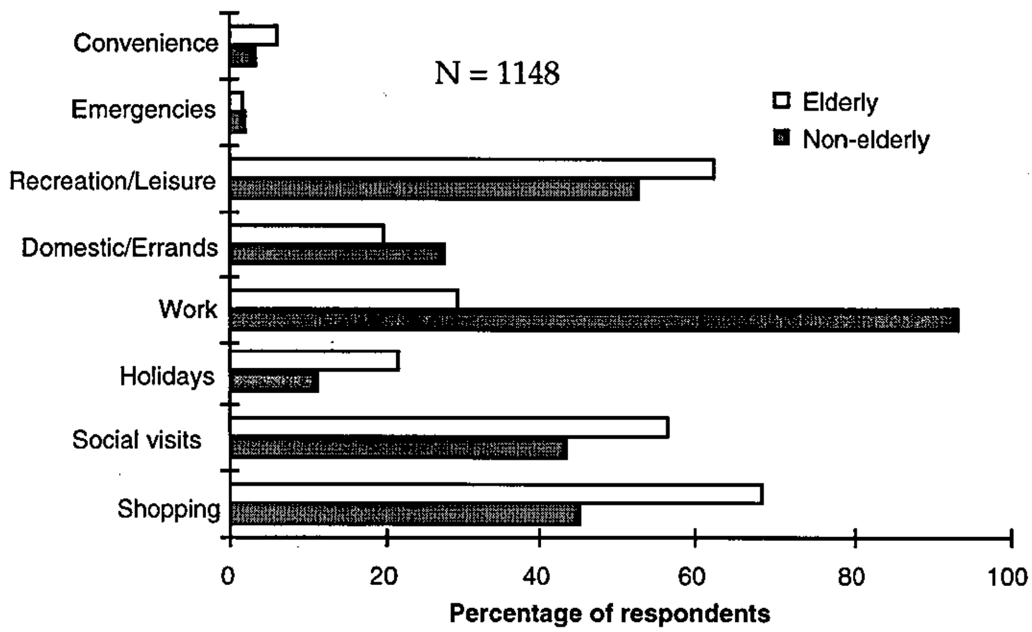


Figure 6.5. Three most important driving activities, by age group.

6.3.3. *Driving Frequency*

Respondents also indicated how often they drive for six pre-specified activities (see Figure 6.6). Elderly respondents drove significantly less frequently for every activity except *shopping*. The largest difference between age groups was for *work* (includes volunteer work). Only 12% of drivers aged < 60 years were unemployed whereas 82% of those 60 years were retired or unemployed.

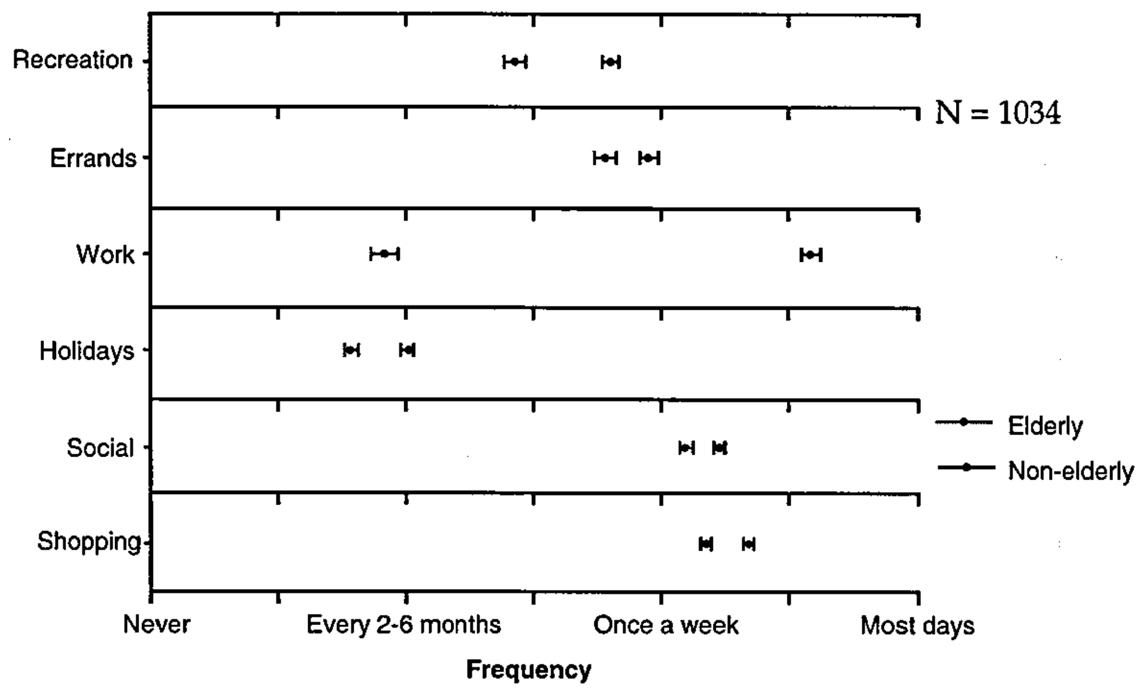


Figure 6.6. Frequency of driving activities, by age group (± 1 standard error).

Figure 6.7 plots the mean total driving frequency across all 6 activities. There is a decline in driving frequency in older age. An analysis of variance was conducted to determine whether driving frequency differed across age group and gender. People drive less frequently with age [$F(5, 1022) = 48.68$, $p < 0.0001$, $\eta^2 = 0.19$]. There was no difference between males and females for the mean total driving frequency.

It should be noted here that there may be some concern about the use of ordinal scales in parametric statistical analyses. However, it is generally accepted that most parametric statistical tests (e.g., ANOVA's) do not require the dependent measures to be on interval scales as long as the assumptions about the normal distribution of the data are met (e.g., Gardner, 1975).

Figure 6.8 plots driving frequency for work with the mean of the other five activities across age group. There is a clear decline in driving frequency for work with increasing old age. The decline is more gradual for other activities. An analysis of variance was conducted to determine whether the mean driving frequency for non-work activities differed across age group and gender. People drove less frequently for non-work activities with age [$F(5, 1035) = 9.01, p < 0.0001, \eta^2 = 0.04$]. There was no gender difference in driving frequency for non-work activities.

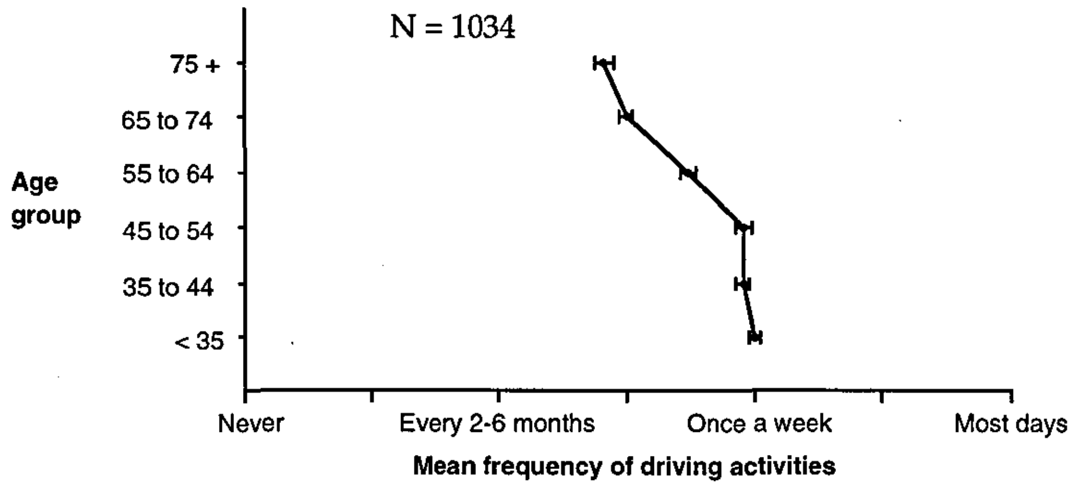


Figure 6.7. Mean frequency of driving activities, by age group (± 1 standard error).

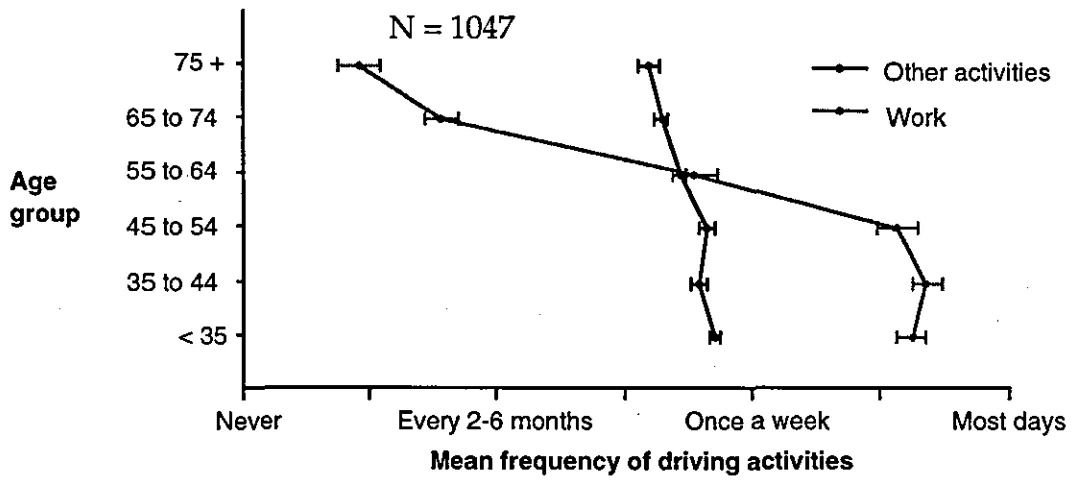


Figure 6.8. Mean frequency of work and other driving activities, by age group (± 1 standard error).

Respondents were asked to rate how many miles they drive in an average week (see Figure 6.9). An analysis of variance was conducted on weekly mileage for gender and age group. Both main effects were significant. People drive less with age [$F(5, 1158) = 21.32, p < 0.0001, \eta^2 = 0.08$] and females drive less than males on average [$F(1, 1158) = 114.24, p < 0.0001, \eta^2$

= 0.08]. The apparent interaction between age group and gender was non-significant at $\alpha = 0.01$.

The X-axis in Figure 6.9 has been transformed to represent equal units of mileage, whereas the ANOVA described in the preceding paragraph is based on the scale for weekly mileage used in the questionnaire. It should be noted here that the weekly mileage measure employed a scale with six unequal intervals. The interval size increases from *less than 10 miles* for the first point to *more than 300 miles* for the last point. This was done to avoid the inevitably skewed distribution that would have arisen with an open-ended question about weekly mileage. Although this type of scale is not ideal for parametric statistics, it was found to be normally distributed. Furthermore, respondents may have had trouble answering if this was an open-ended question (Burns, 1992).

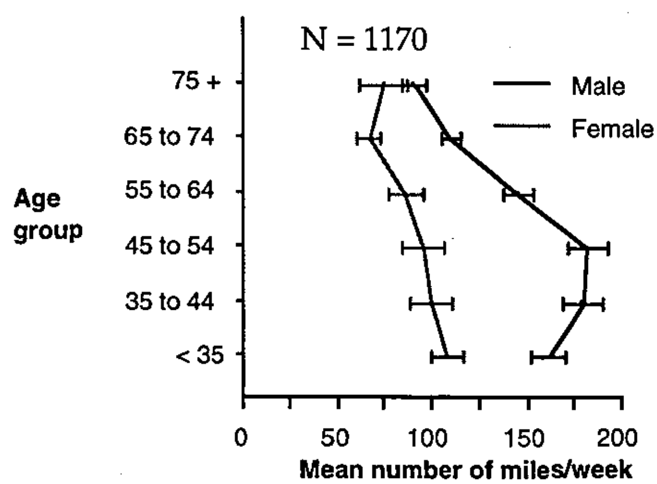


Figure 6.9. Mean number of miles driven per week, by gender and age group (± 1 standard error).

With respect to the type of area in which respondents lived, city dwellers drove least on average (M = 114 miles/week, SD = 93) and people living in rural areas drove most (M = 140 miles/week, SD = 91.5). This trend was significant $[F(3, 1141) = 5.37, p < 0.001, \eta^2 = 0.01]$.

6.3.4. *Number of Unfamiliar and Familiar Trips*

Respondents were asked to estimate the number of trips they had taken in the previous week. They were then asked to estimate if this amount was normal. For most respondents (n = 952), the amount of driving was about average. The others (less, n = 95; more, n = 127) were excluded from the descriptions in this section. The first plot in Figure 6.10 displays the mean number of trips per week in relation to age group. There is a tendency to drive fewer trips with increasing age. The trend across age for unfamiliar trips is less for unfamiliar trips than familiar trips. Figure 6.11 shows a strong decline with increasing age in travel on unfamiliar journeys.

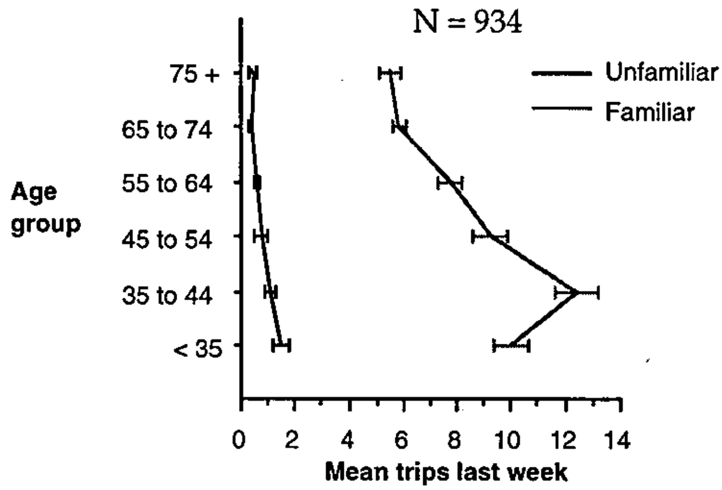


Figure 6.10. Mean number of familiar and unfamiliar trips per week, by age (± 1 standard error).

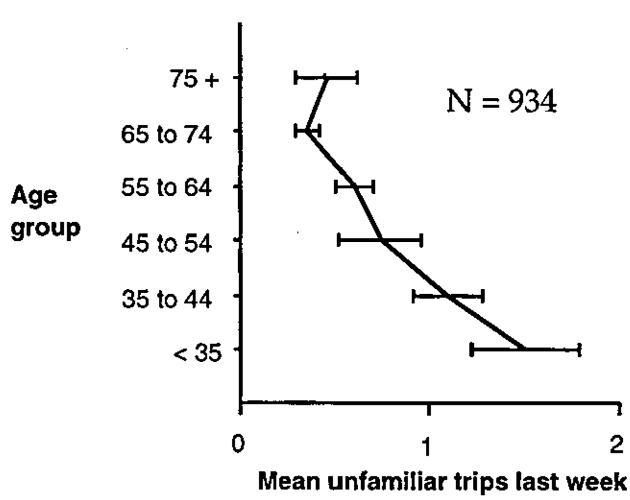


Figure 6.11. Mean number of unfamiliar trips per week, by age (± 1 standard error).

The distribution of the both unfamiliar and familiar trips violated the parametric statistical assumption for a normal distribution; it was leptokurtotic and positively skewed. The nonparametric Mann-Whitney

U test was used to determine if there were significant differences between age (< 60 and 60 years) and gender for the number of familiar and unfamiliar trips. There were highly significant differences found using both the nonparametric and parametric statistics. Non-elderly respondents drive on significantly more familiar trips [$t(932) = 10.1, p < 0.0001$, effect size = 0.64] and unfamiliar trips [$t(932) = 5.41, p < 0.0001$, effect size = 0.35] than the elderly respondents. Effect size is an index of the magnitude of the difference between the means in relation to the standard deviation. It has been suggested, as a rule of thumb, that an effect size around 0.20 is small, 0.50 is medium, and over 0.80 is large (Cohen, 1977). Thus, an effect size of 0.64 represents a medium effect. There were no significant differences found for gender on either familiar or unfamiliar trips.

6.3.5. *Frequency of Unfamiliar Trips*

Respondents were asked to indicate how frequently they drove on unfamiliar journeys within 30 miles of where they lived. Figure 6.12 displays the frequency of these short unfamiliar trips by age group and gender. There were significant main effects for gender [$F(1, 1156) = 12.06, p < 0.001, \eta^2 = 0.01$] and age [$F(5, 1156) = 23.94, p < 0.0001, \eta^2 = 0.09$]. There was no significant interaction. Males and non-elderly drivers tended to drive more frequently on unfamiliar trips.

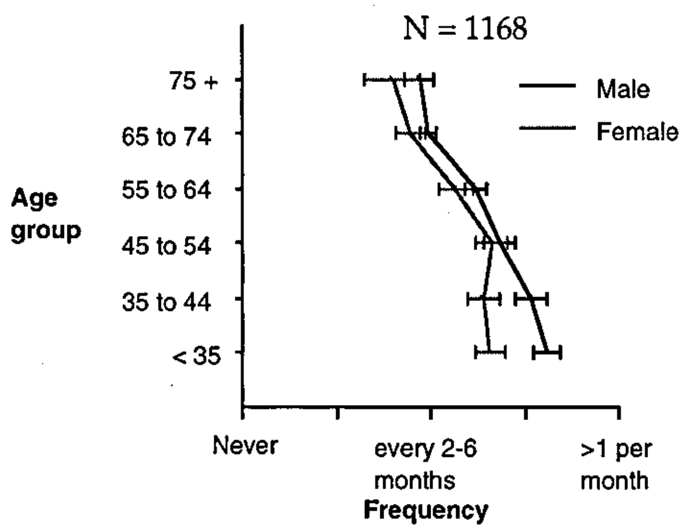


Figure 6.12. Frequency of short unfamiliar trips (< 30 miles), by gender and age group (± 1 standard error).

Respondents were also asked to indicate how frequently they drove on unfamiliar journeys further than 30 miles from where they lived. Figure 6.13 displays the frequency of these longer unfamiliar trips by age group and gender. A similar association was observed with significant main effects for age [$F(5, 1156) = 26.20, p < 0.0001, \eta^2 = 0.10$] and gender [$F(1, 1156) = 36.00, p < 0.0001, \eta^2 = 0.03$]. There was no significant interaction.

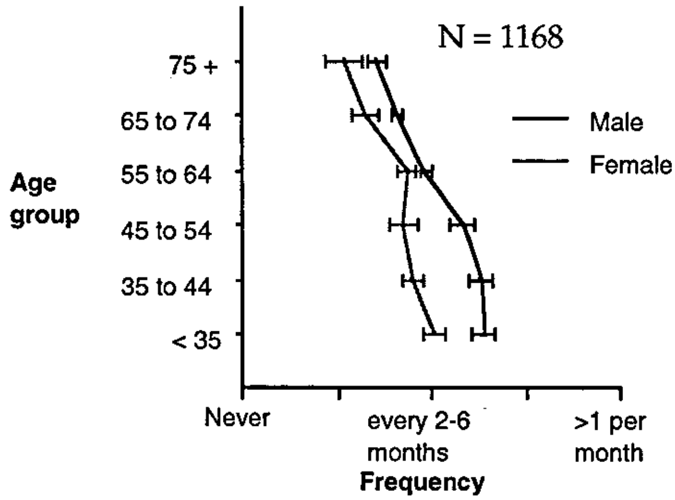


Figure 6.13. Frequency of long unfamiliar journeys (> 30 miles) by gender and age group (± 1 standard error).

6.4. Situations Avoided

Figure 6.14 shows the extent to which older and younger respondents avoid 16 different driving situations or places. Elderly drivers try to avoid all situations more than non-elderly drivers with the exception of road works. Bad weather, rush-hour traffic, road works and town centres are the most avoided situations.

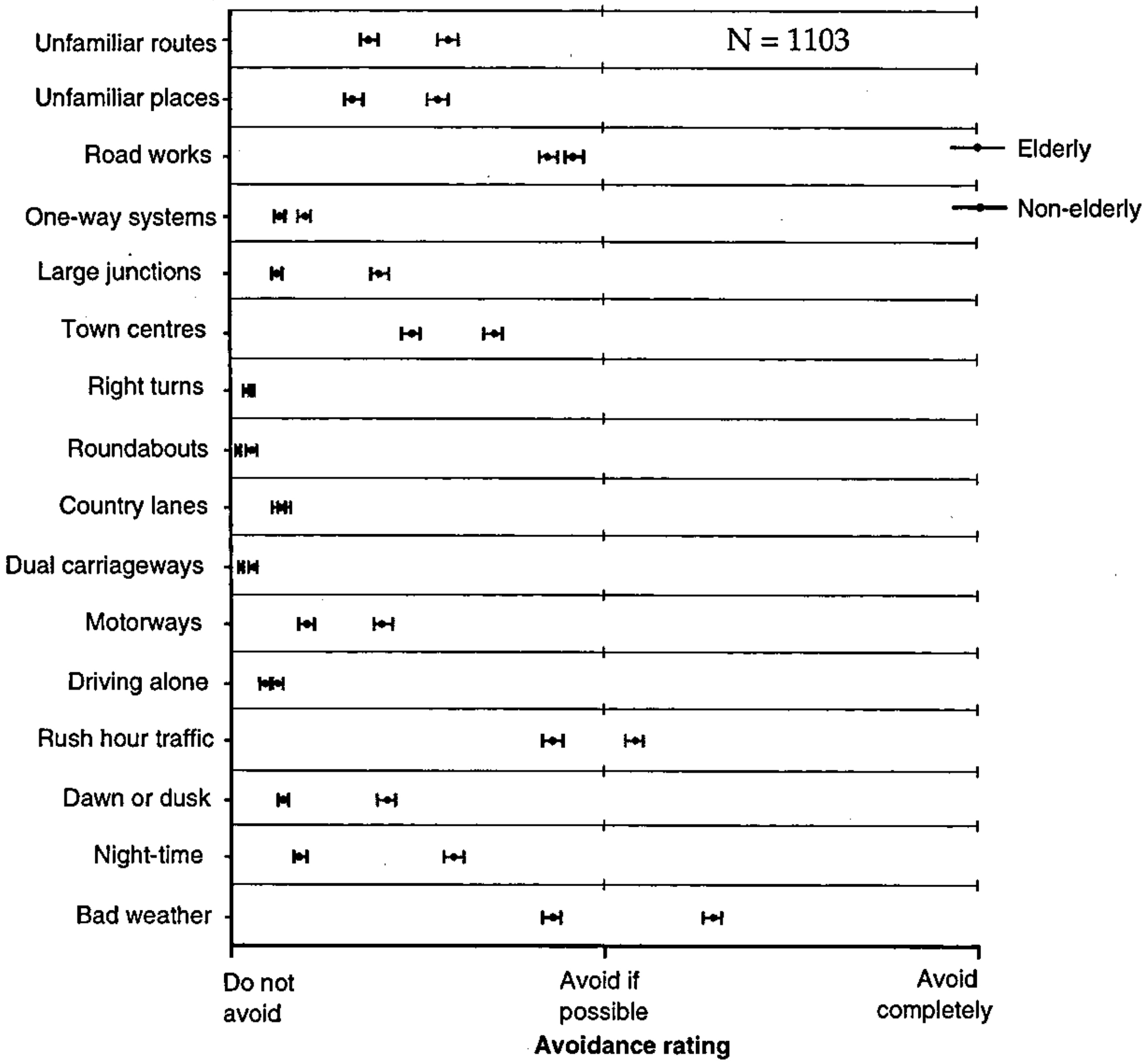


Figure 6.14. Mean avoidance of different situations, by age group.

The mean avoidance ratings for all 16 situations or places are plotted against age groups and gender in Figure 6.15. On average, women drivers avoid these situations more than men [$F(1, 1091) = 15.92$, $p < 0.0001$, $\eta^2 = 0.01$] and drivers avoid these situations more with increasing age [$F(5, 1091) = 26.28$, $p < 0.0001$, $\eta^2 = 0.11$].

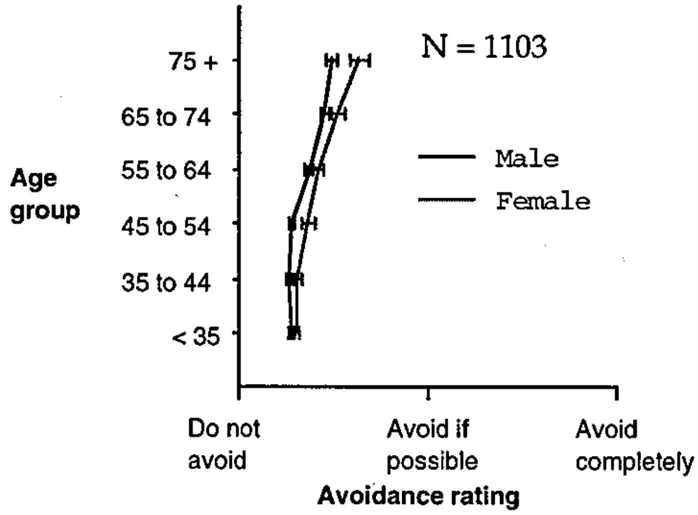


Figure 6.15. Mean total avoidance of situations, by age group and gender .

6.4.1. *Avoidance of Unfamiliar Trips*

Figure 6.16 plots the extent to which drivers avoid unfamiliar routes and places. There is a trend to avoid these situations more with increasing age [$F(5, 1155) = 23.60$, $p < 0.0001$, $\eta^2 = 0.02$]. Also, female drivers avoid unfamiliar routes and places more than male drivers [$F(1, 1155) = 12.51$, $p < 0.0001$, $\eta^2 = 0.05$].

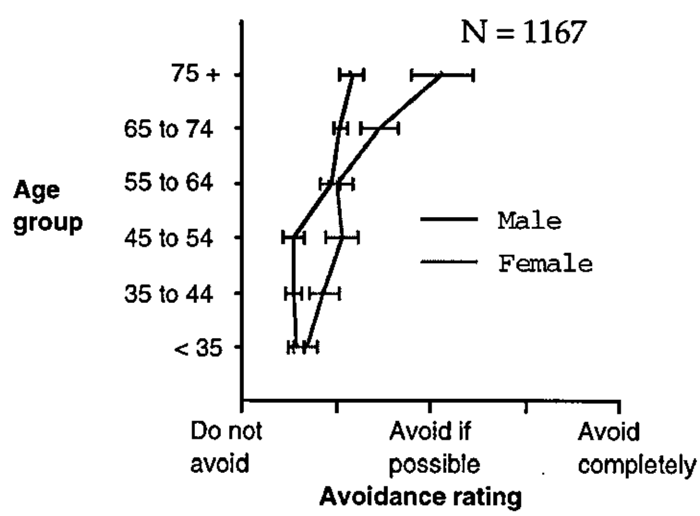


Figure 6.16. Mean avoidance of unfamiliar routes and places, by age group and gender (± 1 standard error).

6.5. Different Planning Strategies

This survey also investigated the route planning strategies of motorists. They were asked to describe how they had planned their last unfamiliar trip. Respondents were given eight pre-determined planning strategies to choose from. Space was also provided for *other* answers. Respondents were permitted to make up to four answers and the question was divided into four different types of routes: motorway, major road or A-road, minor road or B-road, and city.

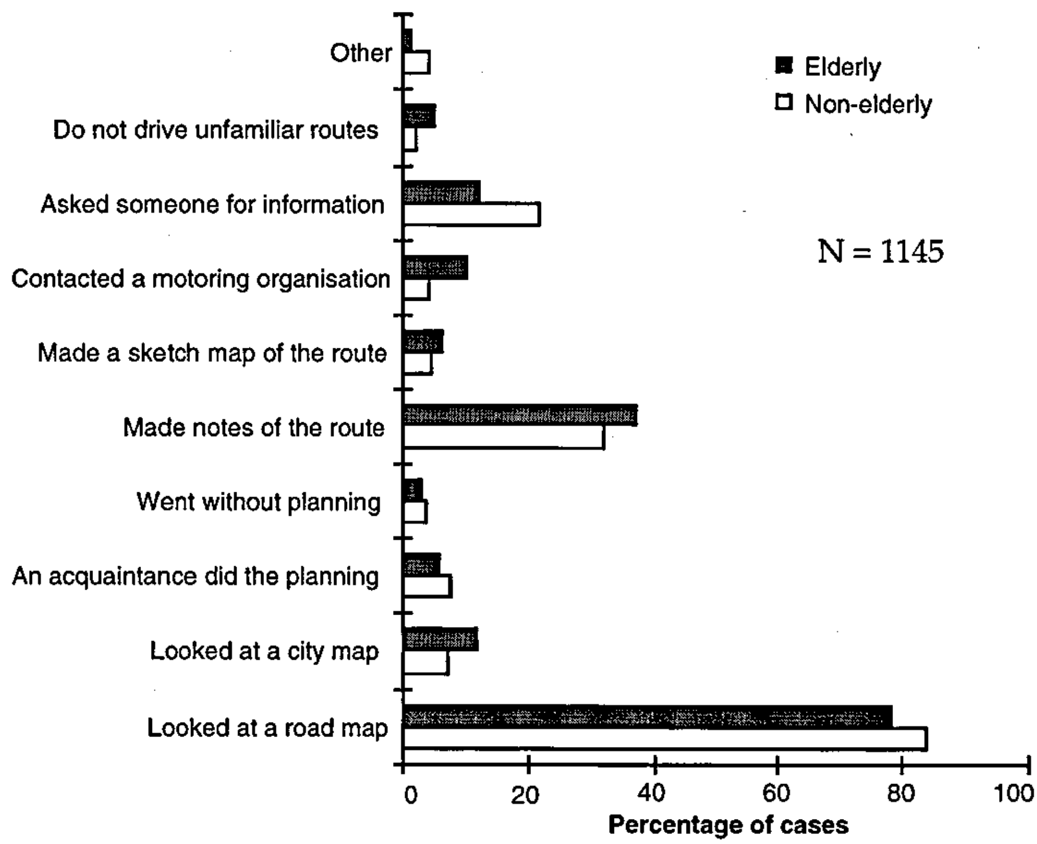


Figure 6.17. Planning strategies for a motorway journey, by age group.

Figure 6.17 is a multiple frequencies plot of the different route planning strategies for a trip along an unfamiliar motorway and the percentage of respondents who use them. These percentages are split by age group. The most common planning strategies for all drivers were to read maps (81%) and take notes of the route (34%). The next most common strategy was to ask someone for route information (17%). A similar distribution of planning strategies was observed for trips along unfamiliar major roads and minor roads. There were only small age differences in planning strategies. The largest difference was that more non-elderly drivers (22%) would ask someone for route information than elderly drivers (12%). There were no gender differences in route planning strategies. On average, drivers listed slightly less than two strategies for planning a trip on an unfamiliar motorway (mean number of responses = 1.72). There were no differences in the number of strategies listed by age group or gender.

Figure 6.18 is a multiple frequencies plot of the different route planning strategies respondents used for their last trip through an unfamiliar city. These percentages are split by age group. The most common planning strategies for all drivers were to consult a street map (53%) or road map (33%) and take notes of the route (20%). Asking someone for route information (20%) was another common strategy. The difference between city planning and the other route types was that drivers would refer to street maps more frequently and use road maps less often. Again, the main age difference was more non-elderly drivers (26%) would ask for route information than older drivers (14%). No difference was observed between male and female planning strategies. Drivers listed between one and two strategies for planning their last trip through an unfamiliar city (mean number of responses = 1.57). Elderly drivers listed a few more strategies (10%) than non-elderly drivers. There were no differences in the number of strategies listed by gender.

There were two additional questions about map use. Eighty-nine percent of respondents kept a road atlas in their cars. There were no gender or age differences. Fifty-two percent of respondents kept a street map in their cars. Only 41% of elderly female drivers kept local street maps in their cars compared to 56% of non-elderly female drivers. A Chi-squared test found this difference to be significant [$\chi^2(1) = 7.07, p < 0.01$].

A majority of drivers said they at least sometimes stop to refer to a map while driving (71%). There were no gender or age differences in self-reported frequency with which people stopped to read a map. Another question asked respondents to indicate how frequently they would read a map or notes while their car was moving. The majority of drivers (56%) would never do this; 24% rarely, 16% sometimes and 4% more often. A Mann-Whitney U-test was conducted to see if there were any age or gender differences in this positively skewed distribution of responses. There was no difference between males and females in tendency to refer to a map or notes while the car was moving, although there was an age difference. Non-elderly drivers, less than 60 years of age, were more inclined to do this than elderly drivers [$Z_{obs} = -10.24, p < 0.0001$]. Seventy-one percent of elderly drivers said they would never read a map or notes while the car was moving.

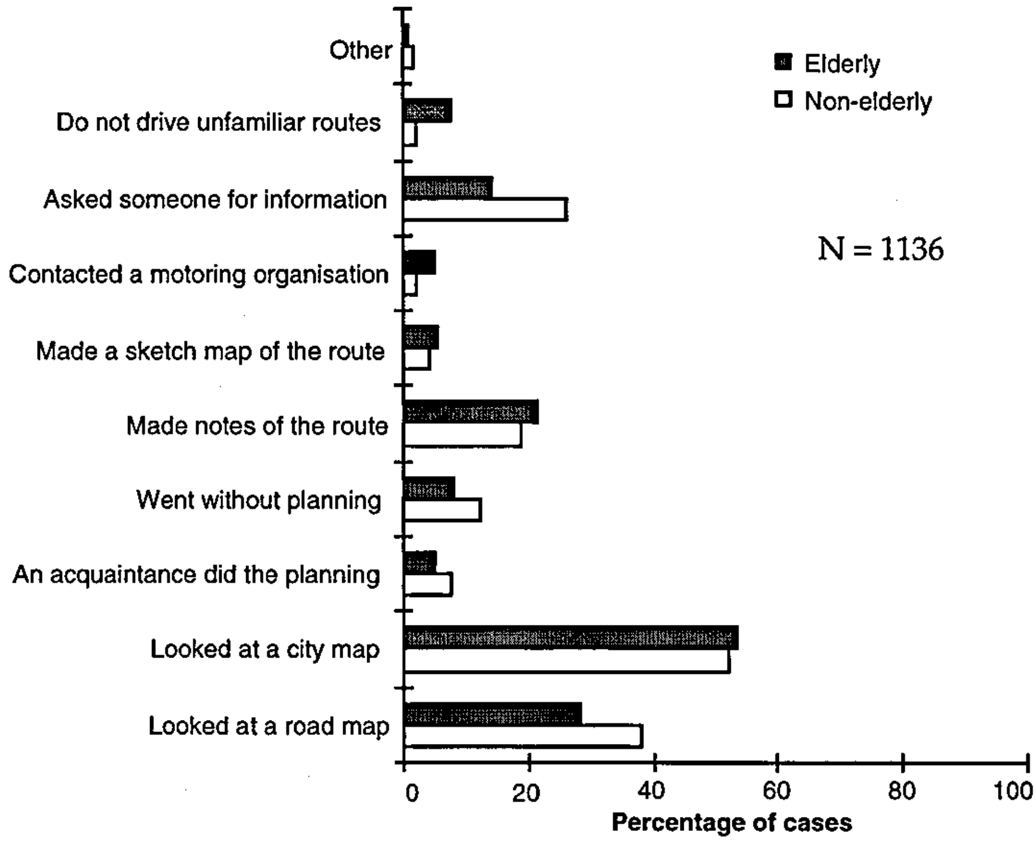


Figure 6.18. Planning strategies for a city trip, by age group.

6.5.1. *Difficulty of Route Planning Strategies*

A set of questions asked respondents to rate the difficulty of using different route planning strategies: preparing route notes, drawing sketch maps, contacting a motoring organisation or asking for route information, and reading a map. Mean difficulty ratings were lowest for maps and notes, and highest for sketches and asking. An analysis of variance was conducted to determine whether there are any gender or age differences in the perceived difficulty of strategies. There was no significant effect for age over all, but there was for gender $[F(1, 577) = 9.44, p < 0.005, \eta^2 = 0.02]$. Female respondents tended to rate preparing sketch maps and reading maps as being more difficult than male respondents.

With respect to individual strategies, there were significant age differences such that maps were rated as being more difficult to read with age $[F(5, 1126) = 3.33, p < 0.01, \eta^2 = 0.01]$, and elderly motorists considered consulting a motoring organisation to be easier $[F(5, 661) = 3.87, p < 0.005, \eta^2 = 0.03]$. *Do not know* responses were high for consulting a motoring organisation. There were significantly fewer *do not know* among the elderly drivers $[\chi^2(1) = 7.8, p < .01]$. The main gender difference was female respondents rated using maps $[F(1, 1126) = 51.45, p < 0.0001, \eta^2 = 0.04]$ and sketches $[F(1, 927) = 13.86, p < 0.005, \eta^2 = 0.01]$ for route planning as being more difficult to use than did the males.

The total number of respondents who answered all of these questions was 585. Many people ticked the *do not know* option. The response rate, or frequency of *do not know* is further evidence for the route planning strategies which people employ. The number of responses for the route planning strategies were map (1143), ask (1063), notes (1043), sketch (944), and motoring organisation (677).

6.6. Different Wayfinding Strategies

After route planning, the survey investigated motorists' wayfinding strategies. Respondents were asked to describe how they find their way while driving. Similar to the route planning question, they were given space for four answers and the question was divided into four different types of routes: motorway, major road or A-road, minor road or B-road, and city. Respondents were given seven pre-determined strategies to choose from. Space was also provided for *other* answers. Figure 6.19 shows the multiple response frequencies of the different wayfinding strategies for a trip on an unfamiliar motorway. These percentages are also broken down by age group. Overall, the most common wayfinding strategies were to rely on memory from studying the route earlier (51%) and/or refer to maps (43%) or notes of the route (29%). The same pattern of strategies were observed for major roads and minor roads. The largest differences were that fewer non-elderly drivers (8%) would stop to ask for directions than elderly drivers (22%) and fewer elderly drivers (46%)

would rely on memory than non-elderly drivers (55%). There were no gender differences in the wayfinding strategies. Drivers listed slightly less than two strategies for wayfinding on an unfamiliar motorway (mean number of responses = 1.74). There were no differences in the number of strategies listed by age group or gender.

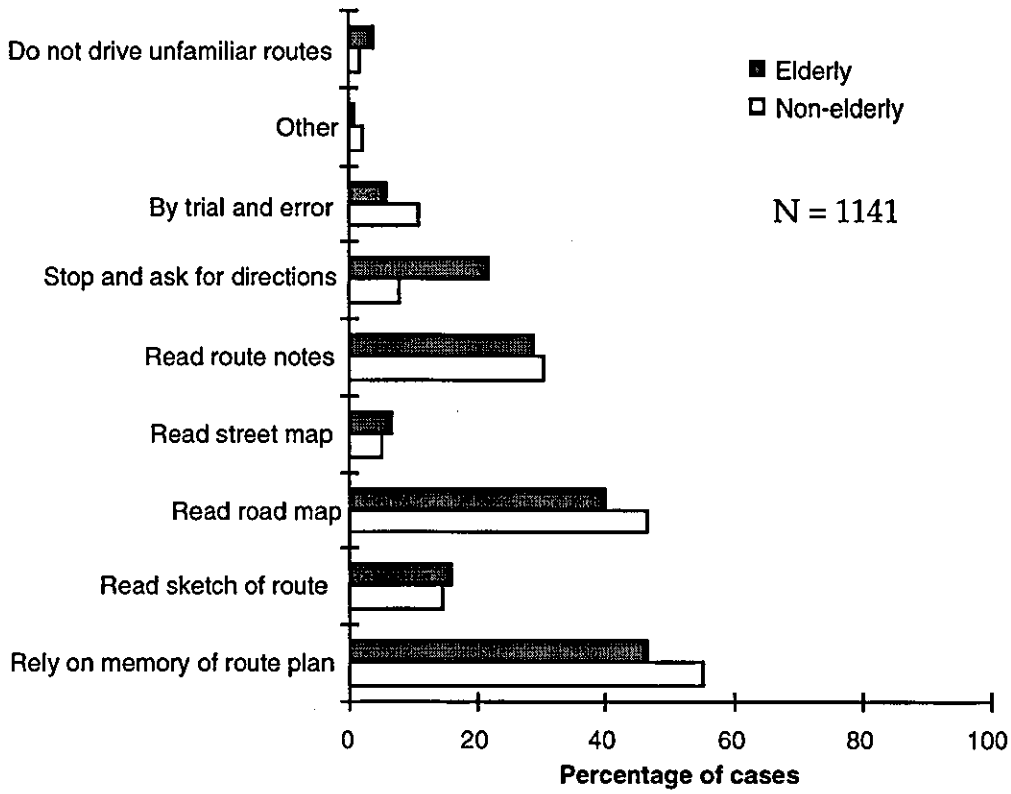


Figure 6.19. Wayfinding strategies for a motorway journey, by age group.

Figure 6.20 shows multiple response frequencies of wayfinding strategies for a trip through an unfamiliar city. The most common wayfinding strategies were stopping to ask for directions (64%) and following a street map (44%). The difference between wayfinding in cities and other route types was that more drivers would stop to ask for directions and fewer would rely on memory. The most prominent age difference was fewer elderly drivers (18%) would rely on memory than non-elderly drivers (27%). Also, fewer elderly drivers (17%) than non-elderly drivers (25%) would read route notes. Little difference was observed between the city wayfinding strategies of males and females. Just under two wayfinding strategies were listed on average (mean number of responses = 1.91). Elderly drivers listed fewer strategies (28%) than non-elderly drivers. Consequently, non-elderly drivers tended to list two wayfinding strategies whereas elderly drivers listed between one and two strategies. There were only minimal differences in the number of strategies listed by gender.

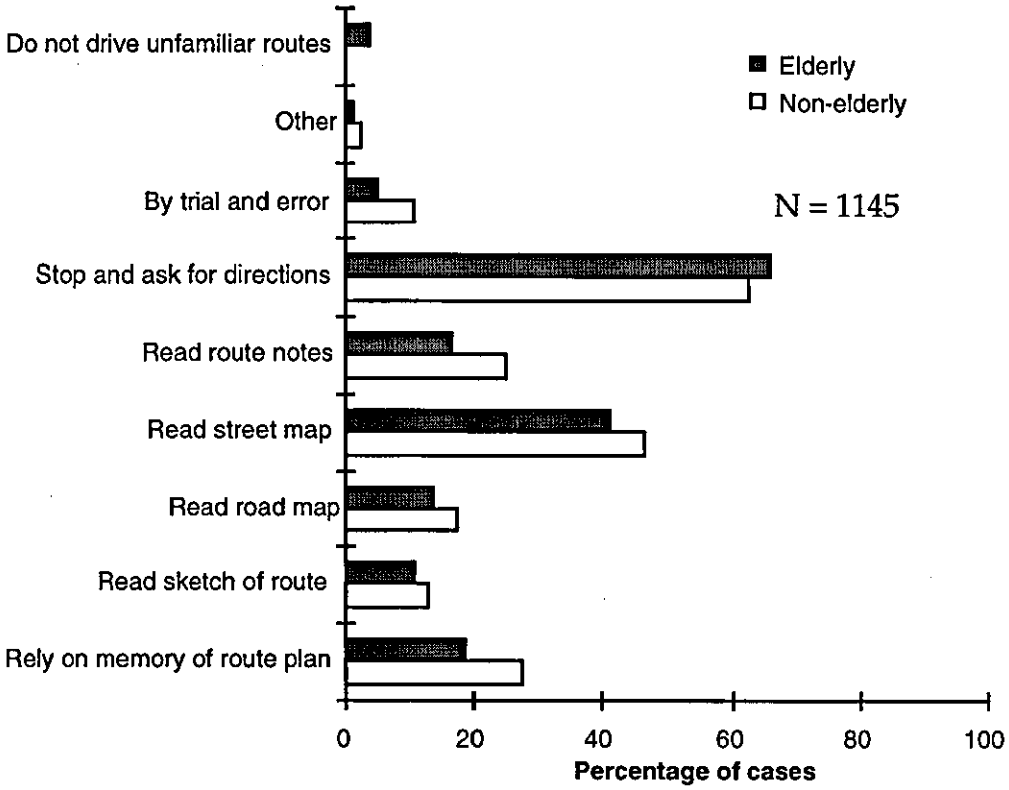


Figure 6.20. Wayfinding strategies for a city trip, by age group.

Absence of a passenger may have implications for wayfinding strategies. A question sought to determine how often respondents drove alone. Fifty-eight percent of respondents often drove alone, 26% drove alone sometimes, 9% rarely and 7% always. Figure 6.21. shows a clear interaction between gender and age group for frequency of driving alone [$F(5, 1157) = 10.13$, $p < 0.0001$, $\eta^2 = 0.04$]. Male respondents tend to drive alone less frequently as they age, whereas women drive alone more frequently with increasing old age. There are also main effects for age [$F(5, 1157) = 3.09$, $p < 0.01$, $\eta^2 = 0.01$] and gender [$F(1, 1157) = 56.39$, $p < 0.0001$, $\eta^2 = 0.04$].

The frequency of driving alone was related to employment. Employed respondents drive alone significantly more frequently than non-working respondents [$t(1158) = -9.0$, $p < 0.0001$, effect size = 0.51].

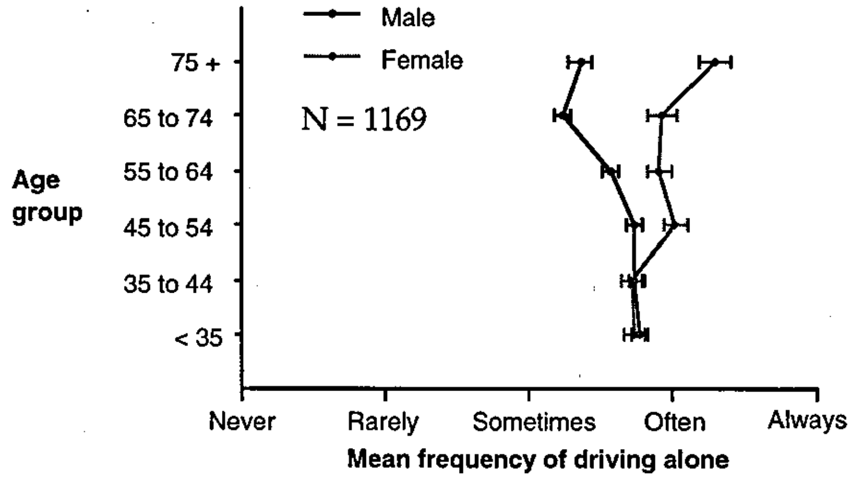


Figure 6.21. Mean frequency of driving alone, by age group and gender (± 1 standard error).

6.7. Wayfinding Information Needs

6.7.1. *Motorways*

Question 37 asked respondents to identify the three most useful types of route information for a trip on a major road. Figure 6.22 plots the frequencies of multiple responses. Most people gave three answers to this question (mean number of responses = 2.93). The three most popular types of information were road numbers (74%), place names (73%) and junction numbers (57%). There were no large differences in the type of information elderly and non-elderly drivers wanted. They had the same three highest preferences. Although there was a reversal in order for highest preferences, such that more elderly drivers wanted road numbers (77%) than place names (71%), and more non-elderly drivers wanted place name information (75%) than road numbers (71%). Males and females were also similar in their preferences, 29% of women wanted landmark information on motorways but only 20% of males. Seventy-six percent of males and 68% of women wanted road number information. Only one respondent selected the *other* option.

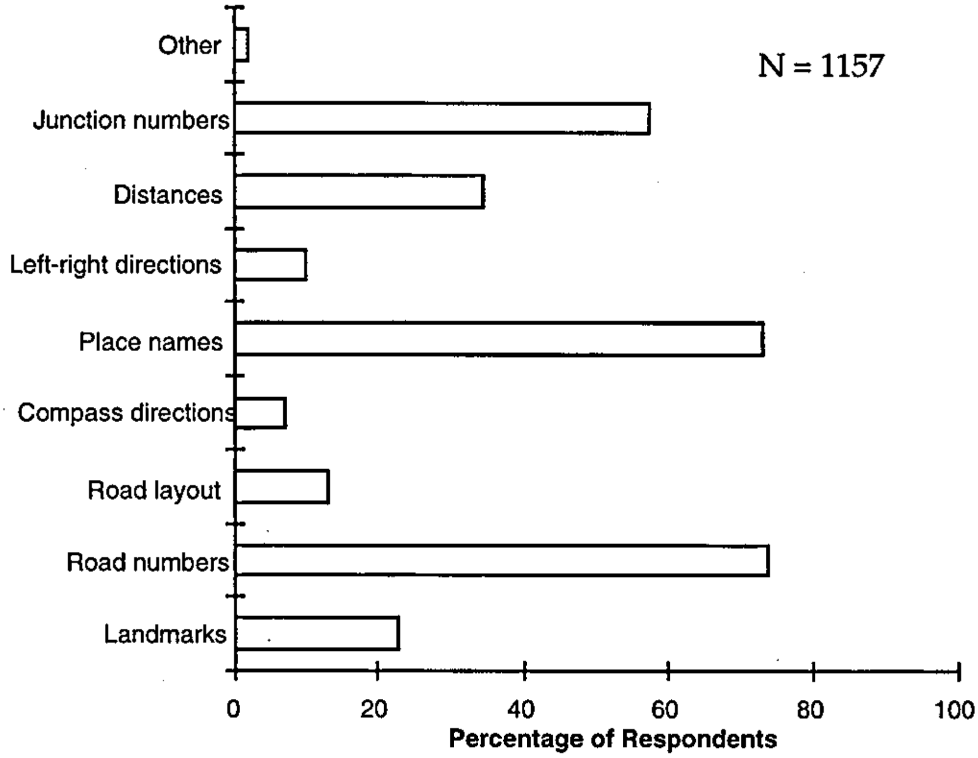


Figure 6.22. Most useful types of route information for a trip on a major road.

6.7.2. *Information for Driving Through Cities and Towns*

Question 38 asked respondents to identify the three most useful types of route information for a trip through a city. Most people gave three answers to this question (mean number of responses = 2.91). Overall, the three most popular types of information were street names (67%), lane position (48%) and landmarks (48%). Figure 6.23 plots the frequencies of multiple responses by age group. There were differences in the type of information elderly and non-elderly drivers wanted. They did not have the same three highest preferences. Most elderly respondents wanted street names (62%), lane position (54%) and road number (46%) information when driving through cities. Most non-elderly drivers wanted street names (72%), landmarks (55%) and lane positions (42%). Street names and road number are two types of path information (See Section 3.54 of Chapter 3). When considered together, they account for 108% of responses irrespective of either gender or age. This percentage exceeds 100 because some respondents choose both road number and street names. The largest difference was where 15% more non-elderly drivers wanted landmark information than did elderly drivers. Males and females were similar in their information needs for city driving. They had the same three highest preferences. The largest difference was 8% more females wanted landmark information. Only one respondent selected the *other* option.

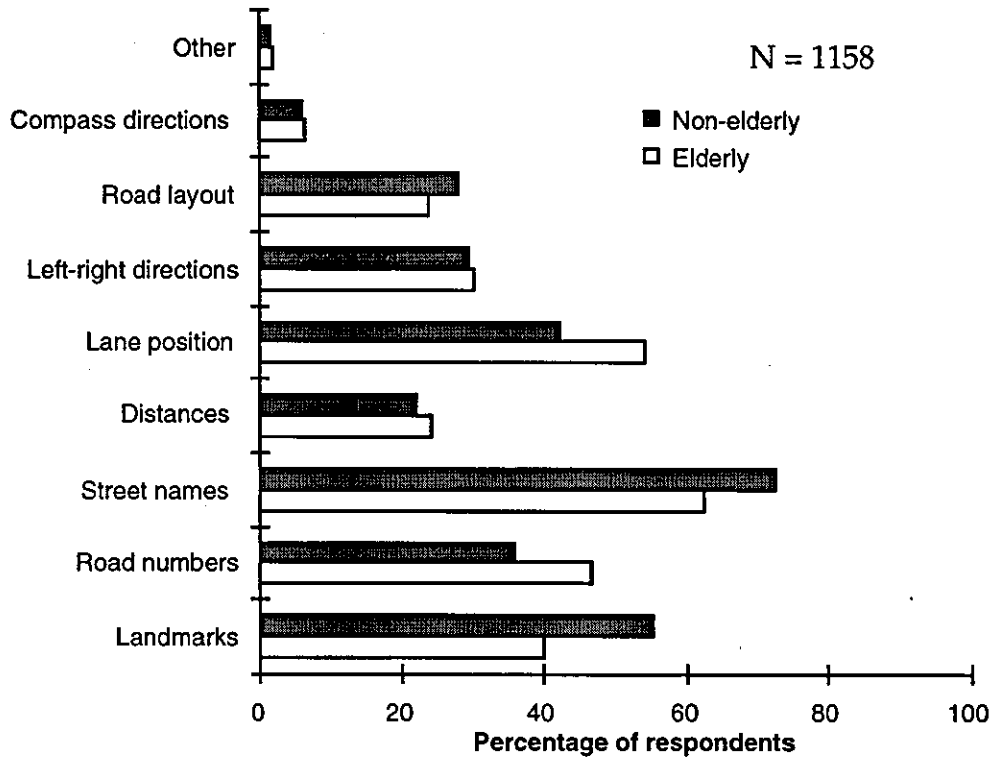


Figure 6.23. Most useful types of route information for a trip through a city, by age group .

6.7.3. *Passenger Information*

Question 39 asked respondents to identify how they would want a passenger to describe the location of a turn. Figure 6.24 plots the frequencies of multiple responses by age group. Again, most people gave three answers to this question (mean number of responses = 2.79). The three most popular types of information were left-right directions (60%), landmarks (44%) and road numbers (41%). With respect to age differences, 16% more elderly drivers listed road numbers among their three responses and 15% more non-elderly drivers listed landmarks.

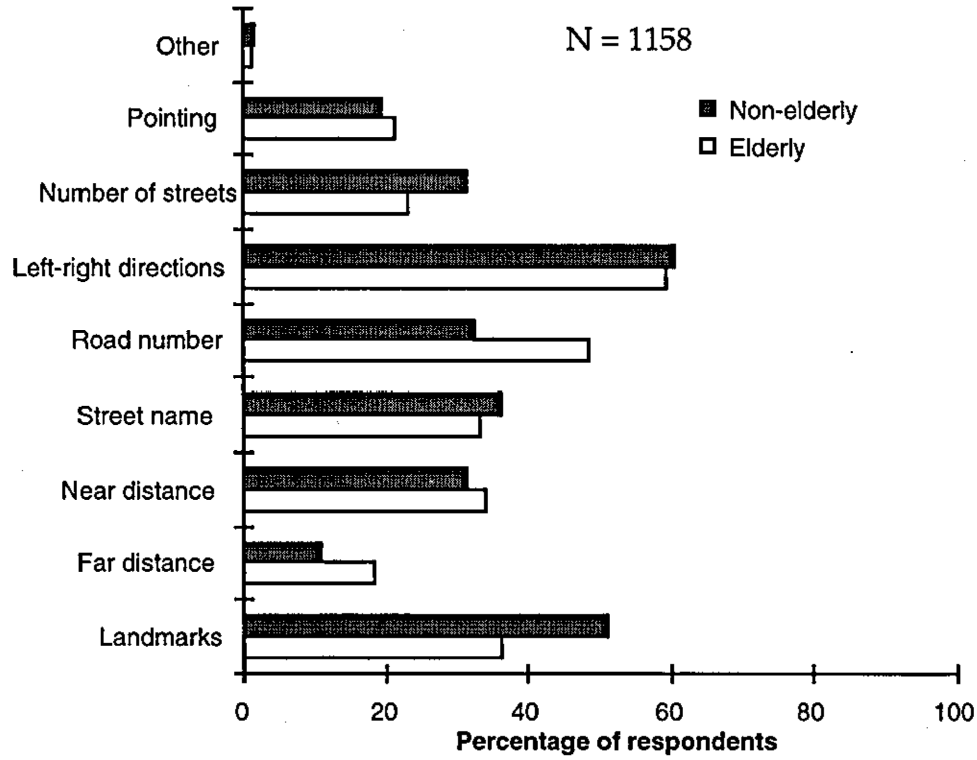


Figure 6.24. Most useful types of route information from a passenger, by age group.

Figure 6.25 plots the frequencies of multiple responses by gender. There are gender differences in preference for turn information They did not have the same three highest preferences. Male respondents wanted left-right directions (60%), road numbers (45%) and landmark (41%) information from a passenger whereas female drivers wanted left-right directions (59%), landmarks (52%) and street names (39%). The largest gender difference was 15% more male drivers wanted road number information than did female drivers. Eleven percent more female drivers wanted landmark information from a passenger. Only seven respondents selected the *other* option.

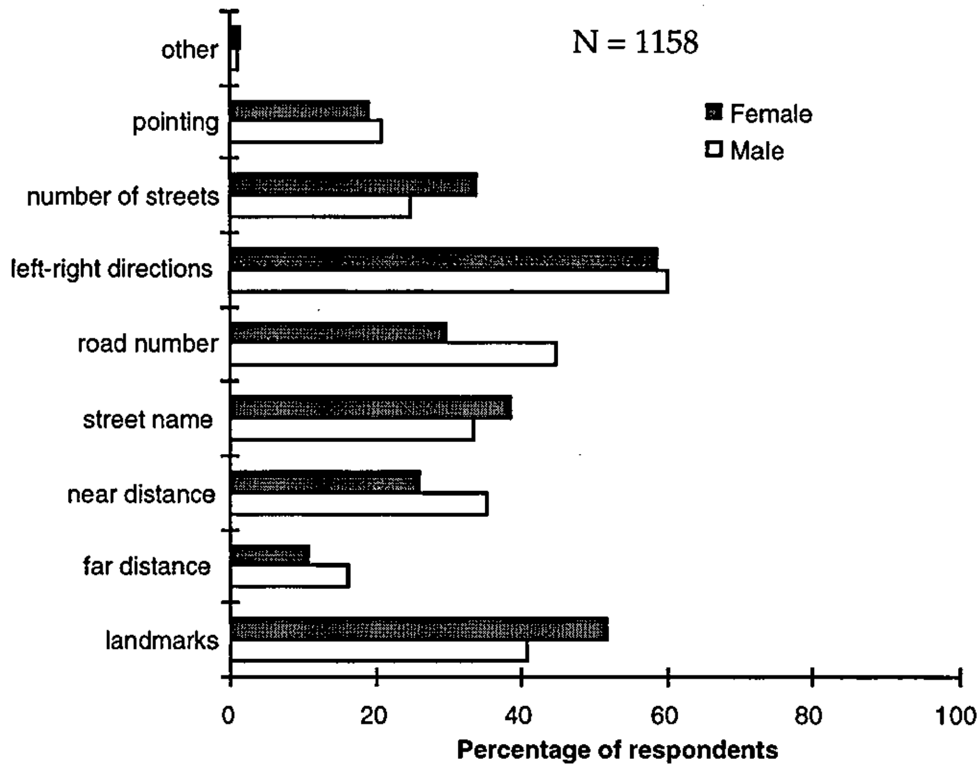


Figure 6.25. Preferences for passenger turn information, by gender.

6.8. Wayfinding Problems

Question 29 asked how satisfied drivers were with their method of wayfinding. There were significant main effects for gender [$F(1, 1151) = 23.83$, $p < 0.0001$, $\eta^2 = 0.02$] on ratings of satisfaction with their method of wayfinding while driving. Males tended to be more satisfied with their method of wayfinding. There were no age effects or interaction between gender and age.

Respondents were also asked to rate their sense of direction. Figure 6.26 displays these ratings in relation to age group and gender. There were no significant main effects for age although there was for gender [$F(1, 1155) = 78.91$, $p < 0.0001$, $\eta^2 = 0.06$]. There was no significant interaction.

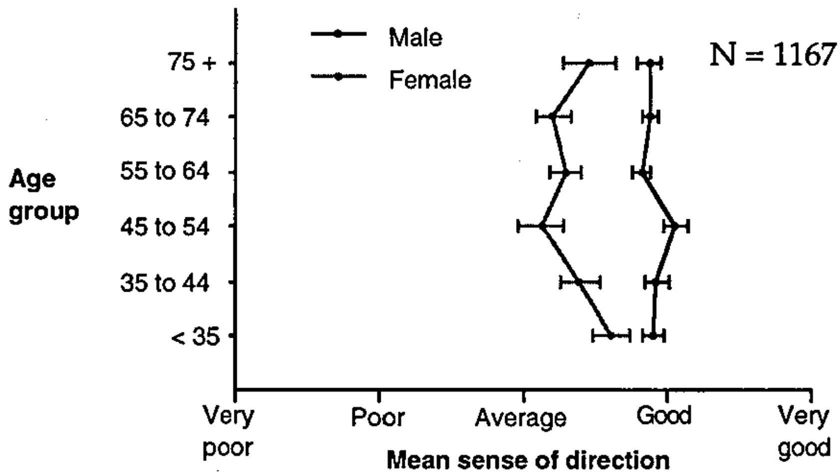


Figure 6.26. Sense of direction, by age group and gender (± 1 standard error).

A question asked respondents to rate their ability to find their way. An ANOVA on wayfinding ability indicated significant main effects for both age [$F(5, 1152) = 6.27, p < 0.0001, \eta^2 = 0.03$] and gender [$F(1, 1155) = 54.08, p < 0.0001, \eta^2 = 0.04$]. There was also a significant interaction between age and gender [$F(5, 1155) = 3.82, p < 0.005, \eta^2 = 0.02$]. Figure 6.27 displays wayfinding ability in relation to age group and gender. The interaction indicates an increase in the difference between males and females self-reported wayfinding ability in later life.

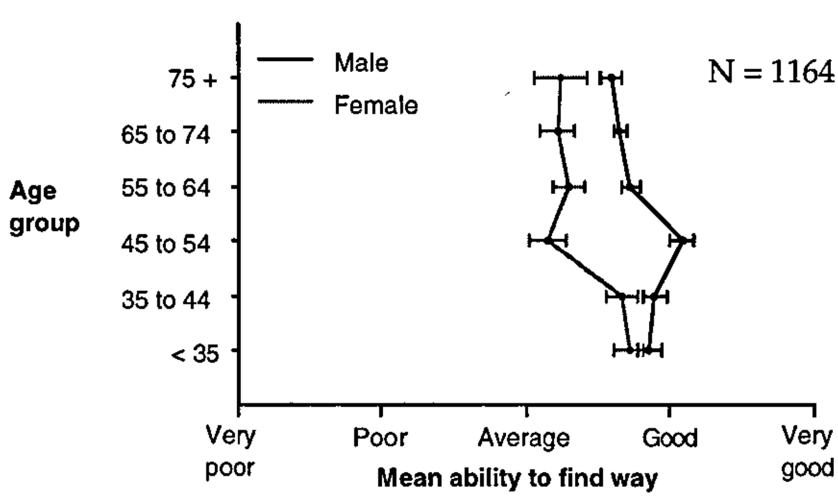


Figure 6.27. Ability to find way, by age group and gender (± 1 standard error).

Figure 6.28 shows the age differences in self-rated abilities to perform some tasks relevant to wayfinding and Figure 6.29 plots the gender differences. On ability to read maps (see Figure 6.30), there were significant age [$F(5, 1147) = 3.36, p < 0.005, \eta^2 = 0.01$] and gender effects [$F(1, 1147) = 89.86, p < 0.0001, \eta^2 = 0.07$]. For ability to distinguish between left and right hand directions, there were also significant age [$F(5, 1149) = 3.13, p < 0.01, \eta^2 = 0.01$] and gender effects [$F(1, 1149) = 89.86, p < 0.0001, \eta^2 = 0.07$] and a significant gender by age interaction [$F(5, 1149) = 3.27, p < 0.0001, \eta^2 = 0.01$]. A plot of this interaction reveals a larger gap between the non-elderly male and female's self-reported ability to distinguish between left and right hand directions (See Figure 6.31). There were no age effects for ability to determine geodetic north, but there was a relatively large and significant main effect for gender [$F(1, 1150) = 115.88, p < 0.0001, \eta^2 = 0.09$]. There were no significant gender effects for either the ability to see messages on road signs or read them while moving but there were significant age effects (see signs, $F(5, 1153) = 4.13, p < 0.0001, \eta^2 = 0.02$; while moving, $F(5, 1153) = 6.67, p < 0.0001, \eta^2 = 0.03$).

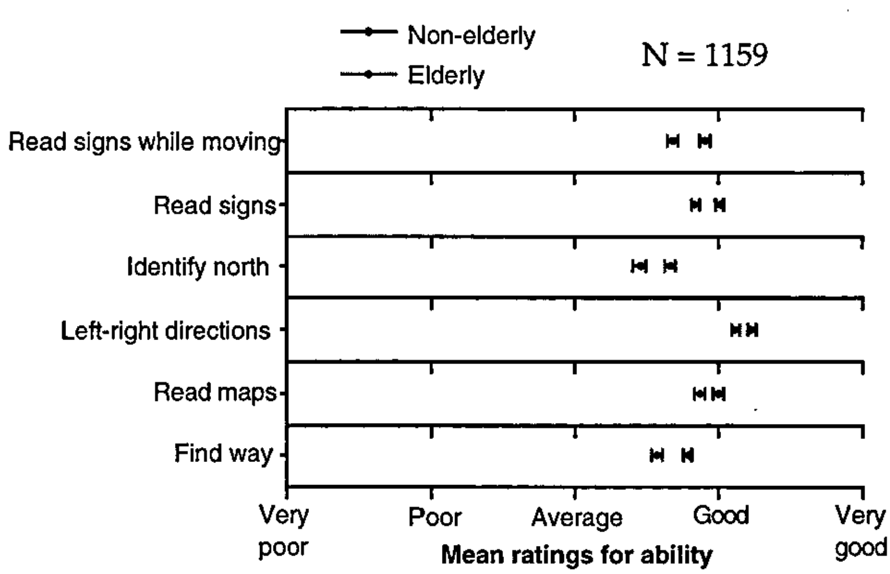


Figure 6.28. Ratings of wayfinding abilities, by age group (± 1 standard error).

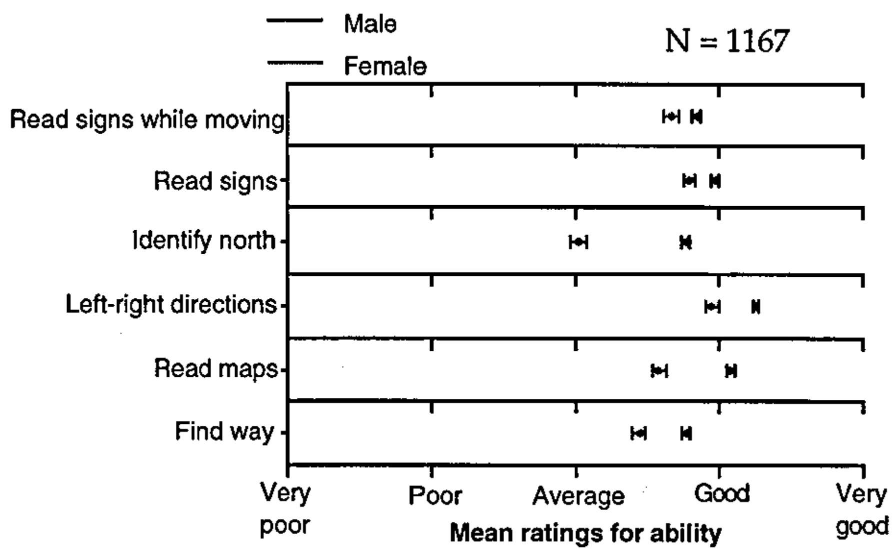


Figure 6.29. Ratings of wayfinding abilities, by gender (± 1 standard error).

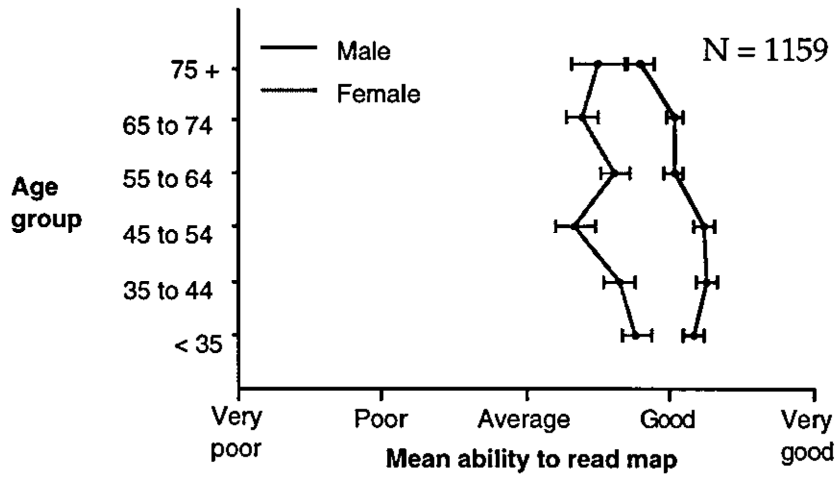


Figure 6.30. Ability to read map, by age group and gender (± 1 standard error).

Respondents rated the frequency with which they experienced a set of different statements relevant to driving (see Figure 6.32). There was only one significant main effect for gender among these statements. Female drivers tended to report a higher frequency of trouble recalling where they had parked their cars [$F(5, 1134) = 7.98$, $p < 0.0001$, $\eta^2 = 0.01$]. There were no age effects for health preventing driving, trouble getting in or out of cars, and forgetting where one had parked. There were significant age main effects for feeling too tried to drive [$F(5, 1129) = 10.03$, $p < 0.0001$, $\eta^2 = 0.04$], turning neck [$F(5, 1139) = 9.90$, $p < 0.0001$, $\eta^2 = 0.04$], turning body [$F(5, 1143)$

= 3.15, $p < 0.0001$, $\eta^2 = 0.01$], wearing glasses [$F(5, 1136) = 17.95$, $p < 0.0001$, $\eta^2 = 0.07$], and slowing to read signs [$F(5, 1138) = 8.45$, $p < 0.0001$, $\eta^2 = 0.04$].

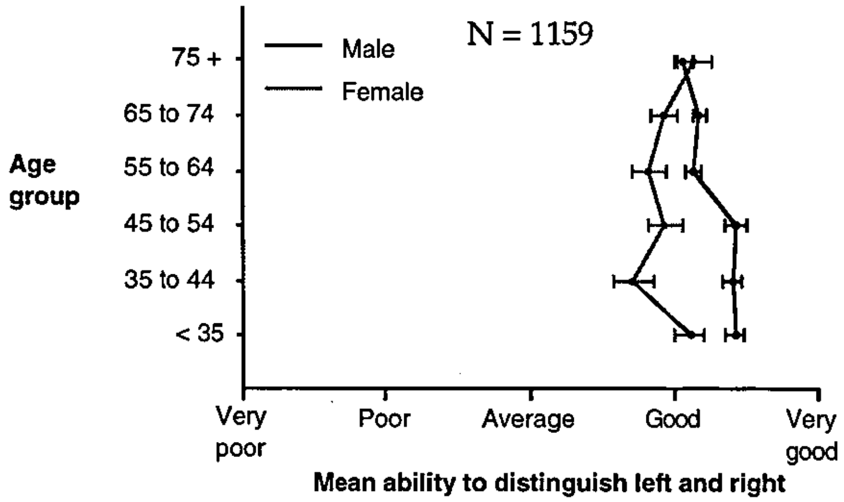


Figure 6.31. Ability to distinguish left and right, by age group and gender (± 1 standard error).

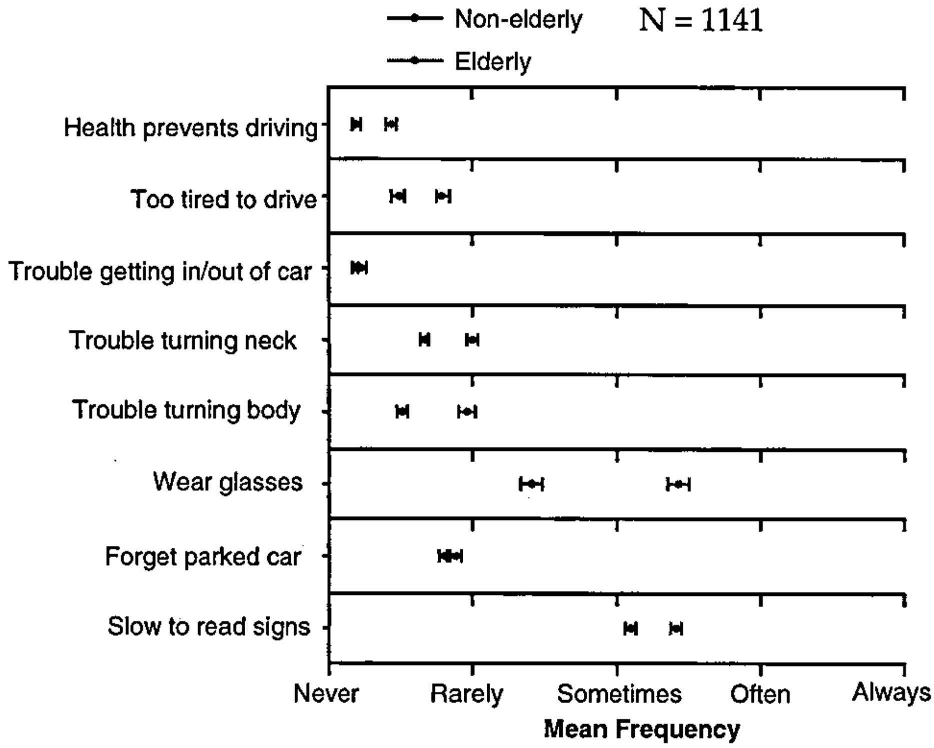


Figure 6.32. Experience with different situations, by age group (± 1 standard error).

Respondents were asked to rate how difficult they found five different wayfinding scenarios on a 5-point scale ranging from *very easy* to *very difficult*. The five scenarios were a motorway, major road, minor road, city and unfamiliar location (e.g., a house). Figure 6.33 shows the mean difficulty ratings for each wayfinding activity split between the elderly and non-elderly respondents. The largest age difference was for motorway driving and wayfinding was most difficult in cities.

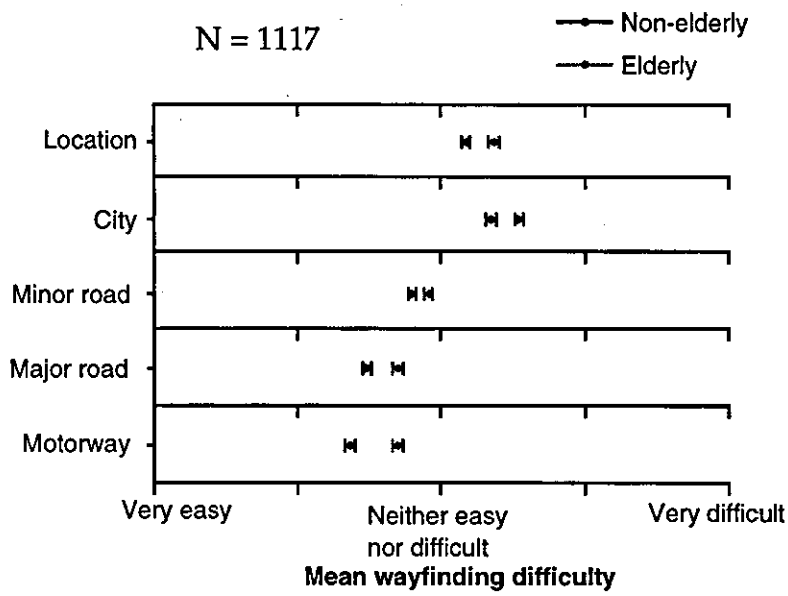


Figure 6.33. Mean difficulty ratings for different types of wayfinding, by age group (± 1 standard error).

Figure 6.34 plots the overall mean difficulty ratings for wayfinding activities in relation to age group and gender. An ANOVA was conducted on the mean difficulty ratings of these wayfinding activities for gender and age group. Both main effects were significant. People rate wayfinding as being more difficult with increasing age [$F(5, 1105) = 6.19, p < 0.0001, \eta^2 = 0.03$] and females rate wayfinding as being more difficult than males [$F(1, 1105) = 30.39, p < 0.0001, \eta^2 = 0.03$].

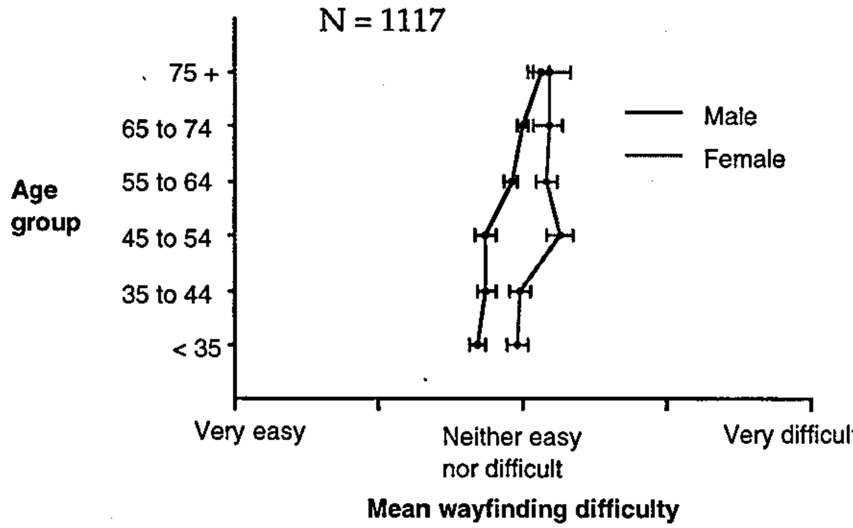


Figure 6.34. Mean difficulty ratings, by age group and gender (± 1 standard error).

6.8.1. *Mobility and Wayfinding Problems*

A hierarchical regression analysis was conducted to determine whether wayfinding problems were related to reduced mobility. These factors are presented in Table 6.1. All variables were examined for their fit with the assumptions of multivariate analysis. The predictor variable that was intended to measure driving experience was dropped from the analysis because of concerns about multicollinearity. It was very highly correlated with the age variable [$r = 0.83, p < 0.01$]. One case was identified as a multivariate outlier using Mahalanobis' distance ($p < 0.001$). This case was omitted from the analysis.

Factors known to influence mobility were simultaneously entered into the first analysis (See Section 2.5.2. of Chapter 2). These variables were age, gender, health, employment, frequency of exercise, area of residence and impact of driving expenses. Variables intended to measure wayfinding problems were entered in the second analysis. These variables were hypothesised to predict variations in mobility that could not be explained by the first set of variables. They were composite measures. *Difficulties wayfinding* is the mean of the five item scale in question 33 of the questionnaire. These questions had respondents rate the difficulty of finding their way in five different road environments (e.g., motorway and cities). Higher mean scores represent more wayfinding difficulties. The internal reliability of this composite scale, as measured by Cronbach's Alpha, was 0.86. *Wayfinding abilities* is the mean of seven items from questions 30 and 31. These questions had people rate different wayfinding skills (e.g., map reading and sense of direction). Higher scores represent better wayfinding abilities. Cronbach's Alpha for this scale was also 0.86. The last composite variable was *Preference to avoid unfamiliar routes.* This consists of two items taken from question 18 in the questionnaire. Higher scores indicate a greater preference to avoid unfamiliar routes and places. Cronbach's Alpha for this scale was 0.93.

Table 6.1. Variables in regression analysis on predictors of mobility.

	Variable	Scale
Criterion variable		
1.	Miles per week (mobility)	• 1 = < 10 miles, 2 = 10 to 39 miles, 3 = 40 to 99 miles, 4 = 100 to 199 miles, 5 = 200 to 300 miles, 6 = > 300 miles.
First set of predictors		
2.	Age	• 21-85 years.
3.	Gender	• Male = 1, Female = 2.
4.	Employment	• Unemployed/ retired = 0, Employed = 1.
5.	Health	• 5 point Likert scale; 1 (very good) to 5 (very poor).
6.	Residential location	• 0 = City, 1 = Suburban/Town, 2 = Village, 3 = Rural.
•	Driving experience	• Years of driving regularly. Dropped because of problems of multicollinearity.
7.	Influence of costs on amount of driving.	• 5 point Likert scale; 1 (decreases a lot) to 5 (increases a lot).
Second set of predictors		
8.	Difficulties wayfinding	• Mean rating for 5 items on a 5 point scale ranging from 1 (very easy) to 5 (very difficult).
9.	Wayfinding abilities	• Mean rating for 7 items on a 5 point scale ranging from very poor to very good.
10.	Preference to avoid unfamiliar routes	• Mean rating for 2 items on a 3 point scale ranging from 1 (do not avoid) to 3 (avoid completely).

The correlations between all the regression variables are presented in Table 6.2. Some of the directions of these correlations need explaining. The positive correlation between health and age indicates more elderly people reported poorer health. The negative correlation between gender and weekly mileage suggests women drive less than men. A positive value for residential location would indicate the respondent lives in a less urban setting. Weekly mileage correlated significantly with all of the predictor variables except residential location and cost of driving.

Table 6.2. Correlation matrix of distance travelled per week and predictor variables.

N = 606	1	2	3	4	5	6	7	8	9
Criterion variable									
1. Miles/week (mobility)	1.00								
First set of predictors									
2. Age	-.21*	1.00							
3. Gender	-.28*	-.19*	1.00						
4. Employment	.31*	-.69*	.07	1.00					
5. Health	-.12*	.22*	-.01	-.23*	1.00				
6. Residential location	.10	.05	.01	-.08	-.04	1.00			
7. Costs of driving.	.06	-.09	.10	.07	-.10	-.01	1.00		
Second set									
8. Difficulties wayfinding	-.19*	.23*	.14*	-.21*	.16*	.03	-.05	1.00	
9. Wayfinding abilities	.25*	-.10	-.25*	.13*	-.25*	-.05	-.01	-.59*	1.00
10. Preference to avoid unfamiliar routes	-.20*	.20*	.04	-.20*	.12*	.04	-.03	.37*	-.26*

* Significant at $p < 0.01$.

Results of the hierarchical regression analysis are presented in Table 6.3. The first set of variables significantly predict weekly driving mileage. The variables with significant regression coefficients (B) are gender, employment and residential location. The squared multiple correlation increases (R^2) significantly when the second set of predictors are entered into the regression equation. Therefore, there is a significant relationship between wayfinding problems and mobility when controlling for the first set of variables. In the second set of predictor variables, *wayfinding abilities* and the *preference to avoid unfamiliar routes* have significant regression coefficients.

This analysis was conducted on half of the sample taken from a random split of the cases. This was done to validate the regression equation (e.g., Stevens, 1992). The regression equation was derived on the first sample

(N = 606) and the prediction equation was applied to the second sample (N = 578) to determine how well it predicts the criterion scores there. The correlation between mileage, as predicted by the first equation, with actual mobility is reflected in Table 6.3. The equation significantly predicted variations in amount of weekly driving for the other sample of respondents.

Table 6.3. Hierarchical regression analysis on mobility (miles/week).

	R^2	R^2 [a]	B [b]	SE B [c]
First set of predictors	.231*			
Age			-.007	.004
Gender			-.834*	.106
Employment			.562*	.124
Health			-.019	.062
Residential location			.184*	.053
Costs of driving.			.100	.077
Fitness			.015	.033
Second set of predictors	.258*	.027*		
Difficulties wayfinding			.085	.091
Wayfinding abilities			.252*	.089
Preference to avoid unfamiliar routes			-.231*	.082
Intercept			2.464*	.541
Cross Validation	.177*			

[a] R^2 is the change in the squared multiple correlation.

[b] B is the unstandardised regression coefficient.

[c] Standard error of the regression coefficient.

* Significant at $p < 0.01$.

Similar analyses were conducted with other measures of mobility. The first analysis used the *number of familiar trips in the preceding week* as the dependent measure. This variable was positively skewed and was given a log transformation to make the distribution normal. The first set of variables significantly predict *number of familiar trips in the preceding week* [R^2= 0.14, $p < 0.0001$]. The variables with significant regression coefficients are employment and age. The squared multiple correlation [$R^2 = 0.02$, $p < 0.0001$] increases significantly when the second set of predictors are entered into the regression equation. This indicates a significant relationship between wayfinding problems and mobility when controlling for the first set of variables. In the second set of predictor variables, as with for weekly mileage, *wayfinding abilities* and the *preference to avoid unfamiliar routes* have significant regression coefficients.

The second analysis used *average driving frequency* across shopping, social visits, holidays, errands and recreation (work was excluded) as the dependent measure. The first set of variables significantly predict *average driving frequency* [R^2= 0.06, p < 0.0001]. The variables with significant regression coefficients are fitness and age. The squared multiple correlation [R^2 = 0.03, p < 0.0001] increases significantly when the second set of predictors are entered into the regression equation. This indicates there is a significant relationship between wayfinding problems and *average driving frequency* when controlling for the first set of variables. Once again, *wayfinding abilities* and the *preference to avoid unfamiliar routes* have significant regression coefficients.

6.8.2. *Frequency of Wayfinding Problems*

Another set of questions asked respondents to indicate the frequency with which they had experienced 16 different pre-coded problems related to wayfinding (e.g., *missed a road sign* and *turned in the wrong direction*) Answers were indicated on a five point scale ranging from *never* to *always*. These 16 pre-coded problems were derived from the most frequent errors reported by drivers during focus group discussions (See Chapter 4) and from a study evaluating navigational aids (Streeter et al., 1985). The most frequent problems reported were: saw a sign too late, missed a sign, and saw turn too late. The least frequent problems were misinterpreted directions, got lost and the route was shorter than expected. An ANOVA was conducted on the frequency of navigation problems by gender and age group. There was no significant main effect for age but there was an effect for gender [$F(1, 1022) = 14.93, p < 0.0001, \eta^2 = 0.01$] such that women reported more frequent problems than males.

Principal components factor analysis with a varimax rotation was conducted on the 16 wayfinding problems. This was done to identify any underlying structure to the problem set. A plot of the eigenvalues was then generated to determine how many factors should be retained.

Cattell's scree test and the *eigenvalue > 1 rule* converged on a three factor solution. The first factor accounted for 36.6% of the variance and the second and third factors accounted for 9.5% and 7% of the variance respectively. The three factors were interpreted on the basis of the higher loading variables (see Table 6.4). *Went off planned route, Found an unexpected turn on the route, Misinterpreted your directions* and *Got lost* loaded highly on the first factor. This was interpreted to represent general decision making errors in wayfinding. *Missed a road sign, Saw a sign too late to respond,* and *Saw a turn too late to respond* loaded highly on the second factor. This was interpreted to represent specific errors in detecting and processing route information. The two variables relating to route length loaded on the third factor. This third factor was interpreted to represent inaccurate expectations of route length. Factor scores did not differ significantly across age groups.

Table 6.4. Rotated factor matrix of wayfinding problems.

	Factor Loadings		
Item	**One**	**Two**	**Three**
missed a sign		**.79**	
saw sign too late		**.85**	
saw turn too late		**.81**	
turned in wrong direction	.51	.46	
turned before you were supposed to	.51	.44	
chose the wrong lane	**.55**		
drove past your destination	.53	.37	
went off planned route	**.68**		
found an unexpected turn	**.60**		
passed the correct exit off roundabout	.45	.36	
route longer			**.83**
route shorter			**.86**
doubts about route	**.58**		
misinterpreted directions	**.66**		
had inaccurate directions	.55		.34
got lost	**.63**		

6.9. Causes of Wayfinding Problems

Respondents were asked *Can you identify any things that have caused you to lose your way while driving.* Six hundred and eighty people answered this open-ended question and 38 different types of responses were identified. These responses fit into five main categories: error, location, situation, individual and signs (see Figure 6.35). These percentages were based on multiple frequencies calculated on a maximum three responses per person. *Signs/ Information* were most frequently reported cause of getting lost. Eighty-three percent of respondents blamed signs for their wayfinding problems. This category included inaccurate directions and a lack of signs, obscured signs, badly placed signs, insufficient information on signs, damaged signs and confusing signs. The remaining four categories had similar rates of response. The *Individual* category (21%) was driver related causes like distracted attention, poor route preparation and poor sense of direction. The *Location* category (21%) referred to specific places which caused problems like road repairs, diversions, one-way road systems, large complicated junctions and new road layouts. The *Situation* category (21%) described particular driving conditions which caused people to lose their way. The most common situations that gave people problems were darkness, heavy traffic and bad weather. The *Error* category (19%) included the following wayfinding errors: missed a sign, wrong lane, missed turn, wrong turn, misread sign and missed a landmark. The five most frequent causes of getting lost, irrespective of these main categories, were: lack of sign (25%), distracted attention (14%), road repairs (13%), obscured signs (12%) and inaccurate directions (11%).

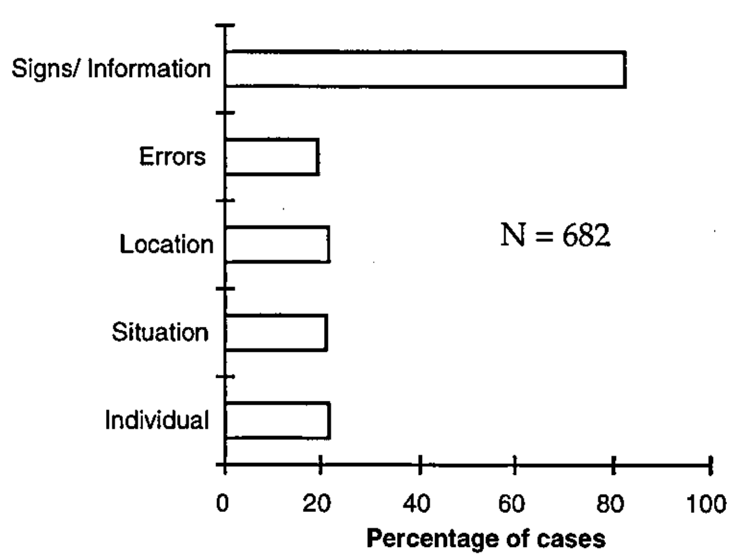


Figure 6. 35. Causes of losing one's way.

Figure 6.36 splits the distribution of the causes of getting lost into elderly (60 years) and non-elderly drivers (< 60 years). A higher percentage of non-elderly (66%) than elderly drivers (50%) answered this question. However, their were no differences in the number of causes listed; between one and two. The pattern of causes is similar although non-elderly drivers blame themselves (e.g., inattention), signs and errors (e.g., missing a turn) more than elderly drivers. Elderly drivers blamed locations (e.g., cities) and situations (e.g., night time) more than non-elderly drivers.

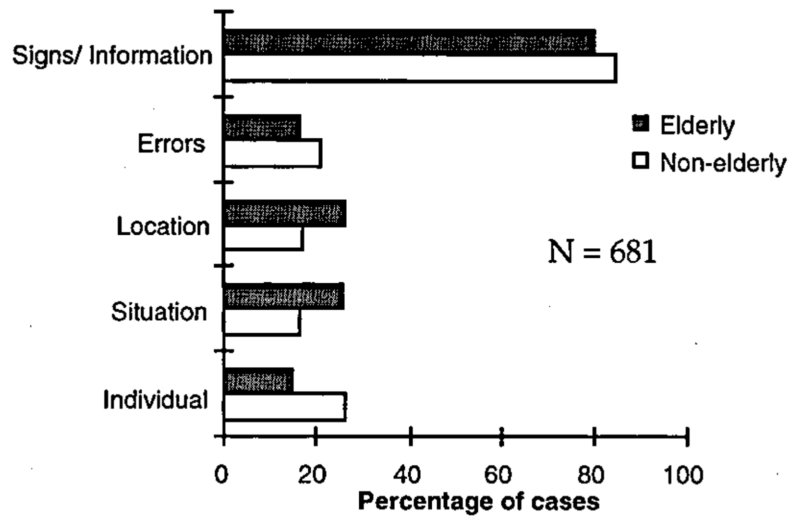


Figure 6.36. Causes of getting lost, by age group.

Figure 6.37 splits the distribution of causes of getting lost by gender. A greater percentage of females (62%) responded to this question than males (56%). They listed a similar number of causes; between one and two responses on average. The pattern of causes is fairly similar although more female drivers blamed errors and themselves than males.

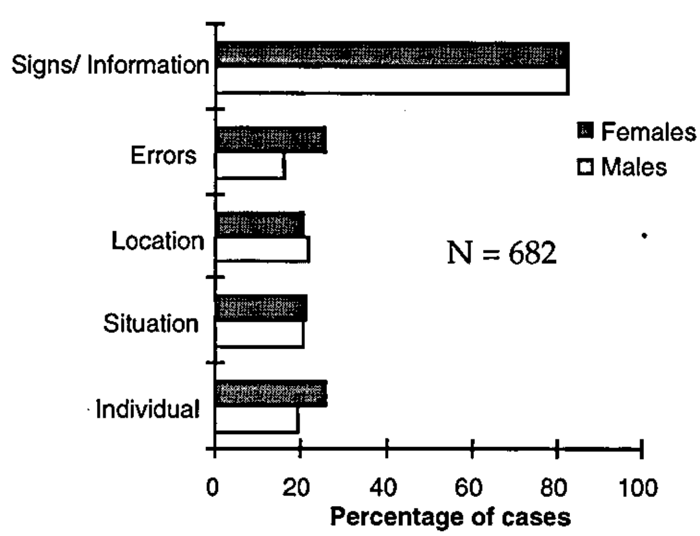


Figure 6.37. Causes of getting lost, by gender.

6.10. Road signs

Figure 6.38 plots the 10 most frequent answers to the question *Are there any changes that you would make to improve road signs.* Five hundred and seventy-two people answered this question. These percentages were based on multiple frequencies calculated on a maximum three responses per person. There were 33 different responses identified. The two most common answers were respondents wanted road signs to be *more frequent* (26.7%) and *more visible* (20.3%). The 23 *other* responses all had frequencies of less than 5%. Some of the more common ones were *more signs in towns, signs with road numbers, less clutter* and *better indicated through-routes in towns.* There were no large age differences among these suggested improvements to signs. Eleven percent more non-elderly drivers wanted signs to be more frequent and 8% more elderly wanted signs to be less obstructed (e.g., by vegetation). With respect to gender differences, 12% more female drivers wanted signs to be more frequent. The percentage of respondents and number of responses did not vary by age group or gender. They tended to suggest between one and two changes to signs.

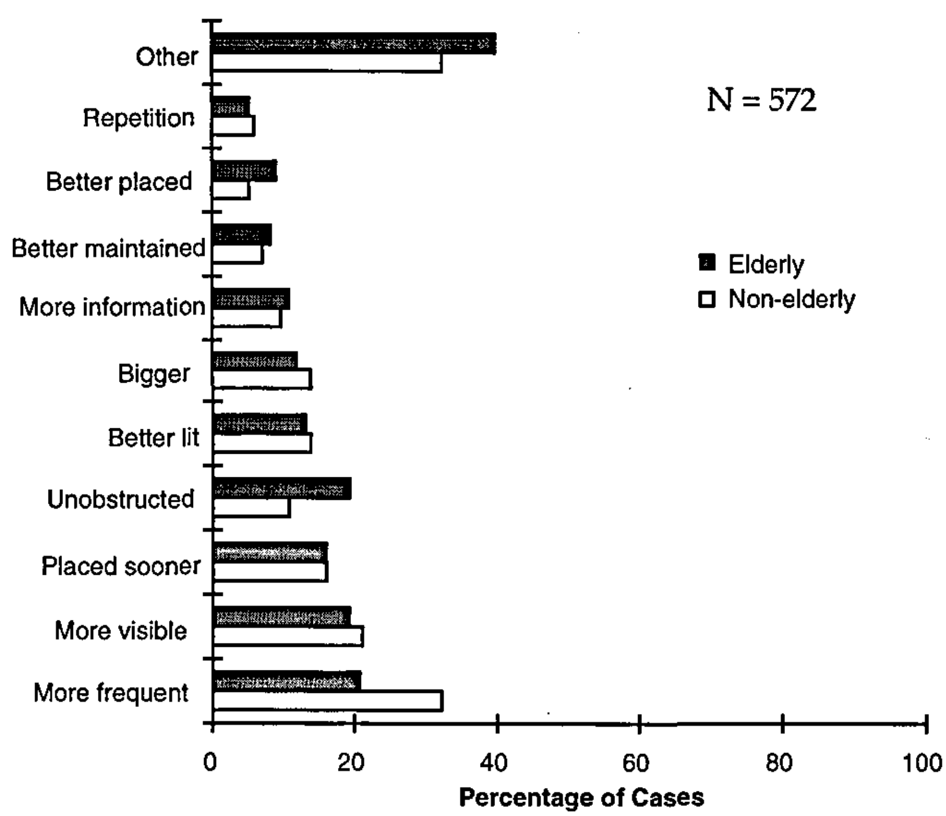
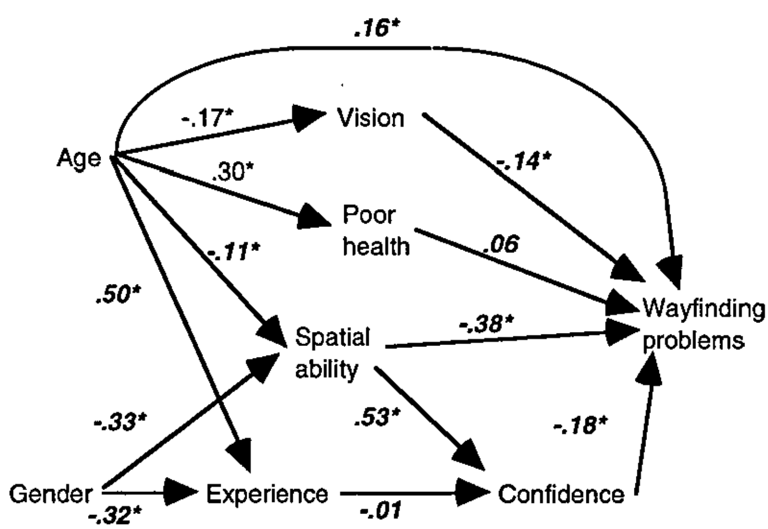


Figure 6.38. Improvements to signs, by age group.

6.11. Individual Wayfinding Performance

Figure 6.39 is a model showing correlations and partial correlations among selected driver characteristics and wayfinding performance. This is the model from Chapter 5 which is a revised form of the model first proposed in Chapter 3. It is a recursive path model such that the proposed relationships are in one direction. The variables tested in this analysis are described in Table 6.5. The relationship between variables that have a single hypothesised predictor (e.g., age with vision) are characterised by simple correlations. Where there is more than one predictor, the relationships are shown with partial correlation values. Therefore, the correlation between age and experience controls for variation that is common with gender. All the path correlations are significant with the exception of experience with confidence and poor health with wayfinding problems.



* indicates significance at α = 0.001. Partial correlations are in italics.

Figure 6.39. Model of the selected individual causes of wayfinding problems with correlations and partial correlations among variables.

Showing the correlations does not demonstrate whether or not this model is correct. Although the model could significantly predict variation in wayfinding problems [$R^2 = 0.52, p < .0001$], there may be a better way to describe the relationships among these eight variables. LISREL, a structural equation modelling technique, was run to determine how well this model fitted the data (Joreskog & Sorbom, 1990). The *adjusted goodness of fit index* from this analysis was poor (*AGFI* = .204). This indicates the model and defined paths do not provide the best description of the inter-relationships among the variables. Further LISREL analyses to derive the optimal path configuration out of the considered variables was considered to be impractical. The outcome of such an analysis would not be informative if some of the variables proved unreliable (see section 7.5.7 for a further discussion).

Table 6.5. Variables in model of individual causes of wayfinding problems.

Variable	Scale
Age	• 21-85 years.
Gender	• Male = 1, Female = 2.
Vision (composite of two measures of ability to see signs; Cronbach's Alpha = .88)	• 5 point Likert scales; 1 (very good) to 5 (very poor).
Poor health (composite of five measures of general health and health for driving; Cronbach's Alpha = .68).	• 5 point Likert scales; 1 (very good) to 5 (very poor).
Spatial ability (composite of five different measures of spatial ability; Cronbach's Alpha = .85).	• 5 point Likert scales; 1 (very good) to 5 (very poor).
Experience (years driven regularly by recent driving experience)	• Years of driving regularly by weekly amount.
Confidence (satisfaction with wayfinding strategies)	• 5 point Likert scale; 1 (decreases a lot) to 5 (increases a lot).
Wayfinding problems (composite measure of difficulties experienced on 5 types of routes; Cronbach's Alpha = .86).	• Mean rating for 5 items on a 5 point scale ranging from 1 (very easy) to 5 (very difficult).

6.12. Consequences of Wayfinding Problems

The questionnaire also asked respondents *How do you feel when you get lost while driving*. Figure 6.40 plots the five most frequent responses by age group. These percentages were also based on multiple response frequencies. There were two responses given on average. The most commonly reported feelings, irrespective of age or gender, were irritation and frustration. Overall, 44% of respondents reported they felt *irritated* when lost. The two most frequent positive adjectives describing feelings when lost were *calm* (16%) and *confident* (14%). The negative adjectives had 75% of the responses and the positive ones had 25%. In terms of age differences, more elderly drivers reported feeling embarrassed and foolish than non-elderly drivers, and more non-elderly drivers reported feeling frustrated and irritated. Figure 6.41 plots gender differences in feelings when lost. A greater percentage of females reported feeling anxious when lost and more males report feeling embarrassed.

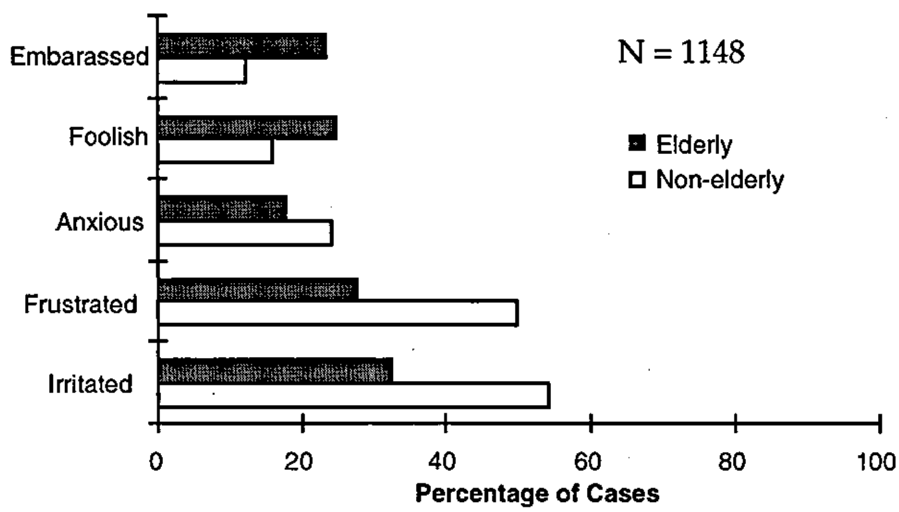


Figure 6.40. Feelings when lost, by age group.

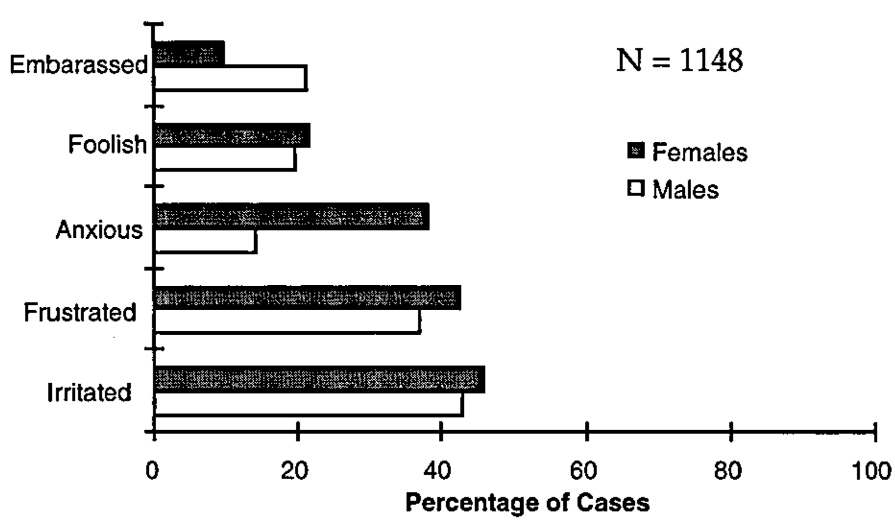


Figure 6.41. Feelings when lost, by gender.

6.13. Chapter Conclusions

The results of the questionnaire survey of driver navigation have been described in this chapter. The most common route planning method was to read a map and take notes of the route. For wayfinding on major roads, drivers stated a preference for road number, place name, and junction information. In cities, they requested information about street names, lane position and landmarks. More drivers under 60 years of age preferred landmark information than did elderly drivers. The most frequent wayfinding errors were: missing a road sign, choosing the wrong lane, and detecting a sign or a turn too late to respond safely. The most frequent reported causes of wayfinding errors were: insufficient, inaccurate, obscured or non-existent traffic signs; inattention or distraction, inaccurate directions; darkness; busy roads and road repairs. As predicted, elderly drivers reported more difficulties wayfinding and this was related to reduced mobility. The proposed path model of the relationship between individual driver characteristics and wayfinding performance did not reliably describe the data, however it could significantly predict performance. These results are discussed in Chapter 7.

Chapter 7: Survey Discussion

7.1. Chapter Summary

In this chapter the results of the questionnaire survey of driver wayfinding are discussed. It examines these results in relation to the research literature and thesis predictions outlined in Chapters 2 and 3. The first section provides a description of respondents' driving activities and mobility. Driver navigation strategies are then considered in relation to route planning and wayfinding. The wayfinding information needs of drivers are also discussed. The majority of this chapter deals with the epidemiology of wayfinding problems. The prevalence, types, causes and implications of these problems are examined. These problems are described according to the theoretical model of wayfinding presented in Chapter 3. Results concerning the influence that individual (e.g., age) and environmental factors (e.g., signs) have on wayfinding performance are also described. This is followed by an assessment of the impact wayfinding problems have on driving mobility. The chapter concludes with a discussion of some potential solutions to driver wayfinding problems.

7.2. Mobility and Driving Activities

This first section describes respondents' driving activities and mobility. The most common method of travelling for respondents of all ages was to drive themselves (77%). This is consistent with reports from U.K. travel surveys (DoT, 1996). In the survey, driving was the preferred method of travel (61%) and it was considered by most (91%) to be very important. The majority of respondents (67%) did not want to change the amount they drove, although the people who drove most wanted to reduce their driving (i.e., younger and male drivers).

Amount of driving varied with residential location. Drivers living in urban areas drove less than those in rural areas. This differential applied across age groups and gender. It is consistent with Gelau et al. (1992) who observed that elderly people from rural environments drive a greater distance and more frequently. It is likely that amount of driving is related to the availability of public transportation and perhaps the proximity of resources and work. This highlights the importance of having access to a car in rural areas where there tends to be less adequate public transport or home support services.

Drivers under 60 years of age rated work, recreation and shopping, as their three most important driving activities. For elderly drivers, the most important activities were recreation, shopping and social visits. The three most important activities are the same across age groups when ignoring work related travel. Younger drivers drove more frequently than elderly drivers, even when removing the influence of commuting travel. This is consistent with other reports (e.g., Rothe et al., 1990).

Ages differences in trips frequency are also reflected in reports of number of trips per week and miles driven per week. People drive significantly less with increasing age and women drive less than men. Furthermore, elderly and female drivers go on significantly fewer trips per week. As predicted, the same applies for number of unfamiliar trips, elderly drivers travel on significantly fewer unfamiliar trips. Also, female drivers travel less frequently on unfamiliar trips.

A higher frequency of unfamiliar trips may not relate to age differences in employment because commuting generally constitutes familiar travel. Although there would certainly be instances of work related unfamiliar travel, it is believed the majority of professions would not require this. Professional drivers (e.g., taxi and lorry drivers) would be the exception because some would report a high frequency of unfamiliar trips.

It has been well documented in the literature that elderly drivers prefer to avoid certain driving situations more than their younger counterparts (e.g., Simms, 1993). Results of the survey supported this evidence. Of 16 situations listed, drivers preferred most to avoid bad weather, rush-hour traffic, road works and town-centres. Drivers generally prefer to avoid these situations more with increasing age and women avoid these driving situations more than men. Consistent with other research (e.g., Rabbitt et al., 1996), drivers prefer to avoid unfamiliar places and routes more with increasing age.

7.3. Route Planning Strategies

Route planning strategies are the navigational preparations that people make before driving to an unfamiliar place. Most drivers read maps to plan their last familiar trip outside of cities (81%). The next most common strategies were to take notes of the route (34%) and to ask someone for route information (17%). Inferential statistical analysis could not be conducted because these strategies were not exclusive; the assumption of independent responses was not met. On average, respondents tended to report a combination of two strategies. Thus, they would make route notes from a map or from information given to them by someone. Route planning strategies did not differ outside of cities (i.e., motorways, A-roads and B-roads). Route planning strategies were similar between young and elderly drivers, except more elderly drivers would ask someone for route information.

The most common strategy for planning routes through unfamiliar cities was to refer to a map 86% (city map 53%, road atlas/maps 33%). Taking route notes (20%) and asking someone for route information (20%) were the next two most popular strategies. The difference between city planning and other route types was that more drivers would use city maps in cities and road atlas/maps outside cities. It is uncertain why 33% of drivers would use road maps for planning routes in cities when a city map would seem more appropriate. Perhaps some respondents felt they could get sufficient information from a road map. Road maps tend to show the major routes through cities. Also, road atlases in the U.K. often contain separate, more detailed maps of major cities and most respondents (89%) have a road atlas/map so they may be more available than a map of a specific unfamiliar city. Specifying that the city was unfamiliar meant driver's experience with that city was limited and they may not have had an opportunity to purchase a city map.

No prior research on route planning strategies has distinguished between route types. Results of the present study suggest that planning strategies do not differ substantially between route types. The main difference is with the type of map used; city street map or road atlas. Over 80% of respondents use maps to plan unfamiliar trips, irrespective of where they are travelling. Results are in accordance with the route planning methods identified in previous research (Mark & McGranaghan, 1988; Streff &

Wallace, 1993) and results of the discussion groups described in Chapter 4. Map use may be the preferred route planning strategy because, for reasons of time and flexibility, they are more effective than verbal means of conveying environmental information (Kirasic & Mathes, 1990). They also provide a configurational representation of the route area which would assist drivers in developing a cognitive map.

The distribution of percentages would suggest elderly drivers generally use a similar combination of strategies as younger drivers to plan unfamiliar routes. There were only minor differences in the route planning strategies between elderly and younger drivers. More younger drivers would ask someone for route information. This was observed across the different route types. It is unlikely this represents a meaningful age difference that would impact on subsequent wayfinding performance and behaviour. Nevertheless, although asking someone for route information was a much less common strategy relative to map reading and note taking, it may be a more effective strategy. A person who has direct and recent experience with travelling a route will be able to provide information that is not available from maps. For example, they can provide specific roadside details that could serve as landmark cues to wayfinding manoeuvres. Also, a consultant who knows the route may be able to describe how to successfully negotiate locations where they themselves had experienced difficulty. Furthermore, the information gained from asking people would differ from the information acquired from maps. A consultant would generally give procedural route information whereas maps would provide configurational information. The configurational information from maps must be translated into procedural route instructions for wayfinding.

The route planning question inquired about the strategy they had used on their last unfamiliar trip. This may not have been their preferred or usual strategy. It could have been a strategy which suited the particular circumstances of the trip or it could reflect planning resources as opposed to a preferred strategy. The question asked drivers about their *last* trip because it was believed this would facilitate more accurate recall of their planning strategies.

Respondents rated perceived difficulty of the different planning methods. The most popular methods of consulting a map and making route notes were considered to be easiest. Elderly and female respondents tended to rate using maps as more difficult than did younger and male respondents. Female drivers also rated making a sketch map of the route as being more difficult than did males. Perceived difficulty of using a planning method does not necessarily relate to performance problems. Differences could reflect attitudes as much as skill. However, respondents' ratings of map reading ability indicated that elderly and female respondents did not rate their abilities as highly as the younger and male respondents.

Previous research has also shown that elderly people have more difficulties reading maps (Aubrey & Dobbs, 1989; 1990). Research on sex differences in map reading ability is inconclusive (e.g., Galea & Kimura, 1993). Differences in map reading ability could be caused by a lack of practice or experience (McCann, 1982; Williamson & McGuinness, 1990). This is a plausible explanation since these groups of drivers drive less often on unfamiliar trips. Driving experience does relate to improved wayfinding performance in unfamiliar buildings among elderly women (Aubrey & Moniz, 1996). Another explanation is that difficulty in map-reading ability relates to poorer spatial ability. Research has also shown gender (e.g., Hyde, 1990) and age differences in spatial ability (e.g., Simon et al., 1992). The present survey identified the same results; self ratings of spatial ability by the elderly and female respondents were lower than the younger and male respondents.

Nearly half the respondents *do not know* how difficult it would be to contact a motoring organisation for route information. More elderly people could answer this question. It is uncertain why more elderly drivers had experience with contacting motoring organisations to get route information. It is unlikely this is related to differential membership between age groups. The sample was split equally across age and known membership to a specific motoring organisation. It is reasonable to posit the differences relate to attitudes toward travelling on unfamiliar trips. Perhaps elderly drivers prefer to, or are able to, seek out more route planning information. Retirement may afford them more time and opportunity for route planning.

7.4. Wayfinding

7.4.1. *Strategies*

Wayfinding strategies are the procedures people use to find their way while driving. They did not differ outside of cities (i.e., motorways, A-roads and B-roads). The most common strategies people would employ for wayfinding on motorways were to rely on memory from planning (51%) and/or refer to maps (43%) or notes of the route (29%). These wayfinding strategies are consistent with the planning strategies. The most common wayfinding strategies for driving through an unfamiliar city were: stopping to ask for directions (64%) and/or reading a street map (44%).

These differences between wayfinding in cities and outside of cities can be explained. The task of driving in cities is likely to be more demanding on people. Wayfinding would also be more difficult in cities because of the higher frequency of decision points and complexity of road layout. This increased complexity of city wayfinding could make it more difficult to memorise and recall routes. Consequently, relying on memory would be a less effective strategy in cities.

Drivers are more likely to stop to ask for directions in cities because it is more feasible; stopping may be easier and there tend to be more people around to ask. Furthermore, asking people in the vicinity of a destination may assist drivers with a particularly complex part of the journey. This is discussed more in the next section (7.4.2). The fact that there are differences between wayfinding within and outside of cities indicates there is a need to distinguish between these environments when examining wayfinding behaviour. Previous research has not made this distinction (e.g., Streff & Wallace, 1993).

There were some age differences in wayfinding strategies; fewer younger drivers would stop to ask for directions and fewer elderly drivers would rely on their memory. It is uncertain why there would be an age difference in the number of drivers who would stop to ask for directions. This difference was not encountered in the discussion groups described in Chapter 4. Perhaps younger drivers are less willing to admit they need assistance. They might consider that stopping to ask for directions reveals a weakness or incompetence. Elderly drivers may not have these concerns. Stopping to ask for directions would not be the most efficient strategy because it can be difficult to find someone to ask or who can provide assistance. Also, stopping to ask strangers can be dangerous. Participants in the discussion groups believed it was more effective and safer to ask someone working (e.g., petrol station attendant) rather than an anonymous person on the street.

A decline in the ability to recall routes has been reported in the literature (Rabbitt et al., 1996). This might explain why fewer elderly drivers rely on memory for wayfinding. Their poorer recall of route information makes memory a less reliable source of wayfinding information. Consequently, they may have learned to adjust their wayfinding strategies to avoid relying on memory because it was a less effective strategy. Another explanation could be that elderly drivers avoid relying on memory, even if it is adequate, because they are less confident in their ability to recall the necessary route information. Younger drivers may be more inclined to rely on their route memory because they are confident in their skills.

With respect to wayfinding with maps, 71% of respondents would stop to refer to a map while en-route. There were no apparent age or gender differences in map use. However, more younger drivers would refer to maps or notes while their car was moving. Most elderly drivers (71%) reported they would never read maps or route notes while the car was moving. This has implications for the use of complex visual in-vehicle route guidance displays. If elderly drivers will not refer to maps or notes while moving, it is unlikely they would refer to visual route guidance displays. Thus route guidance information will have to be presented when the vehicle is stopped or in another modality (i.e., auditory). Chapter 8 investigates these issues further.

The questions on wayfinding strategies specified that respondents were driving alone. This was to avoid confusion over having the wayfinding task split between driver and passenger. Having a passenger can reduce many of the demands of wayfinding and perhaps change the task altogether. Drivers can concentrate on the road when there is a passenger making the wayfinding decisions for them. Since driving with a passenger might be a strategy to avoid problems that are experienced when driving alone, a separate question asked how often respondents drove alone. At least 86% of respondents sometimes drove alone. There was an age by gender interaction in the self-reported frequency of driving alone such that elderly women drive alone more frequently than elderly males. There was no gender difference in the frequency of driving alone amongst younger respondents. It could not be determined whether the trips on which people drove alone were familiar or unfamiliar. Employed drivers drove alone significantly more often than unemployed people. It is uncertain why elderly female respondents drive alone more frequently than males. If anything this is contrary to what was expected. Perhaps elderly female respondents only drive if they are alone or widowed. If they were with another person (i.e., husband) then that person would be driving and they would be a passenger. It was shown that men, given an option, would rather drive than be a passenger. Women did not have as strong a preference to drive.

7.4.2. *Information Needs*

Major Roads

The three most useful types of route information for a trip on a major road were: road numbers (74%), place names (73%) and junction numbers (57%). There were no large age or gender differences in preference for information. As described in Chapter 3, road numbers (e.g., M25) identify path segments which are the channels on which travellers move. They can also describe a location when they intersect with another path. These intersections between paths or decision points are sometimes described by junction numbers (e.g., Junction 20). Junction numbers can be both a point reference and a choice point where drivers have more than one path option. The other information that respondents found useful was place names (e.g., York). Place names describe a location and are a type of landmark. They may represent a specific destination or intermediate destination. As a destination sub-goal, place names can act like a landmark and anchor directions, be a foci for wayfinding and regionalise information (Golledge, 1992).

Cities

Overall, the three most useful types of route information for a trip through an unfamiliar city were: street names (67%), lane position (48%) and landmarks (48%). This is consistent with Schraagen (1990). There were age differences; 15% fewer elderly drivers wanted landmark information than did younger drivers. The largest gender difference was that more women wanted landmark information (8%).

Street names provide similar information to road numbers. They describe path segments and can describe a location when they intersect with another street. Lane position is also a form of path information. Different lanes on a road are essentially different paths because they offer different route options. Lane position also provides implicit information about a forthcoming manoeuvre. For example, the right lane approaching a roundabout is typically the route to executing a right turn.

Landmarks (e.g., a pub) are point references or known places which provide location information (Lynch, 1960). As with places, landmarks can anchor directions, be a foci for wayfinding and regionalise information (Golledge, 1992). Features like buildings, trees, junctions and parks can be landmarks. The importance of landmark information for driver wayfinding has been observed in previous research (e.g., Akamatsu et al., 1994; Burnett et al, 1994). For example, landmark information added to simple left-right route instructions is better than left-right instructions alone (Alm et al, 1992). Alm et al. used landmarks in their study to provide different types of in-vehicle route guidance information: to more clearly define directions, distances and where to stop. They did not investigate which type of information landmarks were most suited to present (e.g., turn location or distance) or what types of landmarks are best (e.g., buildings or traffic lights). These are questions that future research needs to explore.

It is uncertain why fewer elderly drivers want landmark information. Perhaps the elderly drivers, given the option, would prefer path information over landmark information when wayfinding in cities because it is more suitable to the task in that path information is also relevant to manoeuvring. There are a number of problems with landmark information. It is not part of the established route guidance network. Current signing uses place names, path and distance information which can be extracted from a road map. Although place name is a class of landmark, they were presented as separate response options to the question. Landmark is a vague term and the pub example included with the question is just one type of landmark. Road maps do not tend to identify small landmarks like buildings, telephone boxes and traffic lights. However, A-Z style city maps are more detailed and contain parks and some public buildings. These landmarks may not be reliable because their map representation (e.g., text or two dimension overhead outline of the feature) may bear little resemblance to how they appear near the route, or they may not even be visible.

Path information was the most common type of wayfinding information wanted for driving in cities (street name) and on major roads (road number). Otherwise, the information preferred for the environments was different. When driving on major roads people tended to want junction numbers and place names, and for cities they wanted lane position and landmarks. Differences between environments and response options (see below) would explain the motorists' preferences for different types of information. However, as mentioned in the discussion of strategies, there may also be differences in the type of wayfinding tasks which are performed within these two general route categories. First it should be stated that many unfamiliar trips would involve travel on both route types and that they are not exclusive; drivers can travel through cities on major roads.

Information on major roads may be suited for travelling between regions. Driving in cities will involve both the macro-level wayfinding as on major roads and micro-level destination pinpointing. The need for information, or uncertainty, tends to increase with proximity to a destination and wayfinding becomes more difficult (Gordon & Wood, 1970). An example of the less demanding macro-level wayfinding would be finding a main path through a city and travelling along it to the vicinity of one's destination. The micro-level wayfinding starts as one nears a destination. This type of wayfinding would involve more navigational degrees of freedom and could be characterised by a sequence of frequent decisions that focus onto a precise destination.

It may be difficult to make a clear comparison between locational differences in wayfinding information needs because the questions had some different response options. In the questionnaire, the information needs for wayfinding on a major road were coded to account for obvious differences in the environments. For example, junction information is only relevant to cities when travelling on a major road because it is specific to major roads. There were two different response options on each question: street names and lane position for cities, and place names and junction numbers for major roads. These were among the most preferred responses. Differences between the response options could explain this result. However, it is important to note that respondents had space to give *other* responses if they did not find the options they wanted (only one respondent selected the *other* option).

Turn Information

Respondents were asked to identify how they would want a passenger to describe the location of a turn. If a passenger was giving turn information, respondents requested they provide left-right directions, landmarks and road numbers. Proportionally, more elderly drivers preferred road numbers and more younger drivers preferred landmarks. This is consistent with the age differences found in preferences for city wayfinding information. With respect to gender differences, more male drivers wanted road number information from a passenger than did female drivers, whereas more females wanted landmark information. A greater female preference for landmark information has been observed in previous research (Galea & Kimura, 1993), although not in the context of driver wayfinding. Galea and Kimura, in a study of route-learning abilities, found that women have a better recall of landmarks whereas men were more efficient at overall route learning. The authors use an evolutionary explanation to account for these differences.

It should be noted that drivers may not know what information they really need to find their way safely and efficiently. Preferences may not necessarily be equated with effectiveness. The questions in the survey only identified the information people wanted and not what supports good wayfinding. The appropriateness of these different types of information for communicating wayfinding instructions remains to be determined. This is discussed again later in this Chapter. Future research needs to investigate the safety and effectiveness of these different types of wayfinding information. Chapter 8 addresses some of these issues.

7.5. Wayfinding Problems

7.5.1. *Prevalence of Wayfinding Problems*

Experience with 16 different pre-coded wayfinding problems was rated by respondents (see Table 6.4). The most frequent problems reported were saw a sign too late, missed a sign, and saw turn too late. The least frequent problems were misinterpreted directions, got lost and the route was shorter than expected. The difference between the more and less frequent wayfinding problems may relate to their severity. Minor wayfinding errors like missing a sign occurred more frequently than more serious errors like getting lost. Differences among the types of errors are discussed more in the next section.

Female drivers reported more frequent problems than males. This is consistent with previous research (e.g., Devlin & Bernstein, 1995). Although it was expected elderly drivers would experience more frequent wayfinding problems, there was no significant age difference. There is no research to draw comparisons with this finding. One explanation is that elderly drivers may not commit frequent wayfinding errors because they prefer to avoid unfamiliar routes and places. Perhaps they drive in familiar places where they know their way and will not make mistakes, whereas younger drivers may be less concerned about making mistakes. Similarly, the question may not have been suitable to detect an age difference in the frequency of reported problems. Ratings were to be made in relation to wayfinding as opposed to general experience so as to avoid confusion about exposure. However, respondents may have been rating their general experience with the problem set. In this case it would be expected that elderly drivers encounter less frequent wayfinding problems because they drive less often.

Another question asked respondents to rate the difficulty of different wayfinding activities (city, minor road, major road, motorway, and finding a location). As predicted, people rated wayfinding as being more difficult with increasing age. Female drivers found wayfinding more difficult than males. The same trends were found for the question that had respondents rate their wayfinding abilities. Although there is no comparable research on wayfinding problems in cars, similar results have been reported about perceptions of wayfinding difficulties on foot (Devlin & Bernstein, 1995).

7.5.2. *Types of Wayfinding Errors*

Principal components factor analysis of the 16 wayfinding problems identified three factors. The first factor appeared to represent general decision making errors in wayfinding. *went off planned route, found an unexpected turn on the route, misinterpreted your directions* and *got lost* loaded highest on this factor. The second factor was interpreted to represent specific errors in detecting and processing route information. *Missed a road sign, saw a sign too late to respond,* and *saw a turn too late to respond* loaded highest on this second factor. The two variables relating to route length loaded on the third factor. This third factor was interpreted to represent inaccurate expectations of route length. The third factor may be less important because its items were among the least frequently reported. Therefore, the main distinction among the set of wayfinding errors is between the first two factors; 1) decision making errors and 2) errors arising from the faulty detection of route information.

7.5.3. *Causes of Wayfinding Problems*

Respondents were asked to identify things which caused them to lose their way while driving. Responses were classified according to five main categories: error, location, situation, individual and signs/information. *Signs/ information* were the most frequent cause of getting lost (83%). This category included inaccurate directions and a lack of signs, obscured signs, badly placed signs, insufficient information on signs, damaged signs and confusing signs. Twenty percent of drivers reported causes amongst each of the other categories. The *individual* category was for driver related causes like distracted attention, poor route preparation and poor sense of direction. The *location* category referred to specific places which caused problems like road repairs, diversions, one-way road systems, large complicated junctions and new road layouts. The *situation* category described particular driving conditions which caused people to lose their way. The most common situations that gave people problems were darkness, heavy traffic and bad weather. The *error* category referred to types of wayfinding errors like missed a sign, wrong lane, missed turn, wrong turn, misread sign and missed a landmark. The five most frequent causes of losing their way, regardless of the main categories, were: lack of sign, distracted attention, road repairs, obscured signs and inaccurate directions.

This question referred to *getting lost*. Interpretations of *getting lost* could have ranged from being slightly disoriented to being completely lost (no idea where one is located or in which direction to travel). Responses might have varied if the question asked about situations where people went off their planned route or about what caused them problems while finding their destination. The different interpretations of this question are reflected in differences among the responses. The *error* category is the oddity because respondents attributed the cause of their getting lost to an error. This is the most immediate or proximate cause of getting lost. The four other types of causes precede these errors in the series of events leading up to a driver getting lost. Thus, problems with information, situation, location and individuals cause wayfinding errors which then cause drivers to become lost.

7.5.4. Model of Wayfinding Errors

The causes of wayfinding problems were examined in relation to the theoretical model proposed in Chapter 3 (see Figure 7.1 and 3.2). Existing theory on human error was applied to the context of wayfinding in an attempt to explain the problems. Reason (1990) defines an error as an occasion in which "...a planned sequence of mental or physical activities fails to achieve its intended outcome..." p. 9. The intended outcome in wayfinding would be to travel safely and efficiently to one's destination. Theory on human error has identified some basic types of errors. The three main categories of human error are mistakes, slips and lapses (Norman, 1988; Reason, 1990). Mistakes are incorrect intended responses caused by a misinterpretation or flaw in the choice of responses (Reason, 1990). They can be the result of limitations in perception, memory and cognition (Wickens, 1990). Slips refer to errors where the plan was correct but it was incorrectly executed (Reason, 1990). For example, a driver might turn left at a familiar junction onto the route he normally takes to work when his actual intention was to continue straight on to go shopping. Lapses are the omission of a necessary response and tend to be the consequence of memory failures (Reason, 1990). For example, a driver may neglect to turn where he had planned because he was distracted.

Figure 7.1 describes the types of errors and where they are likely to occur in the wayfinding process. In consideration of the results of this study and the wayfinding process, it is believed that on an unfamiliar route, the bulk of wayfinding errors are *mistakes*. The distinction between wayfinding errors on familiar and unfamiliar routes is important. Parker, Reason, Manstead and Stradling (1995) categorised the 24 different aberrant driving activities on their *Driving Behaviour Questionnaire* into mistakes, lapses or violations. Three of these 24 activities constituted wayfinding errors: *wrong lane at roundabout/junction*, *take wrong exit from roundabout*, and *take more usual route by error*. Parker et al. categorised all three of these errors as lapses. However, this classification fails to consider the importance of route familiarity. The first two errors would be lapses if the

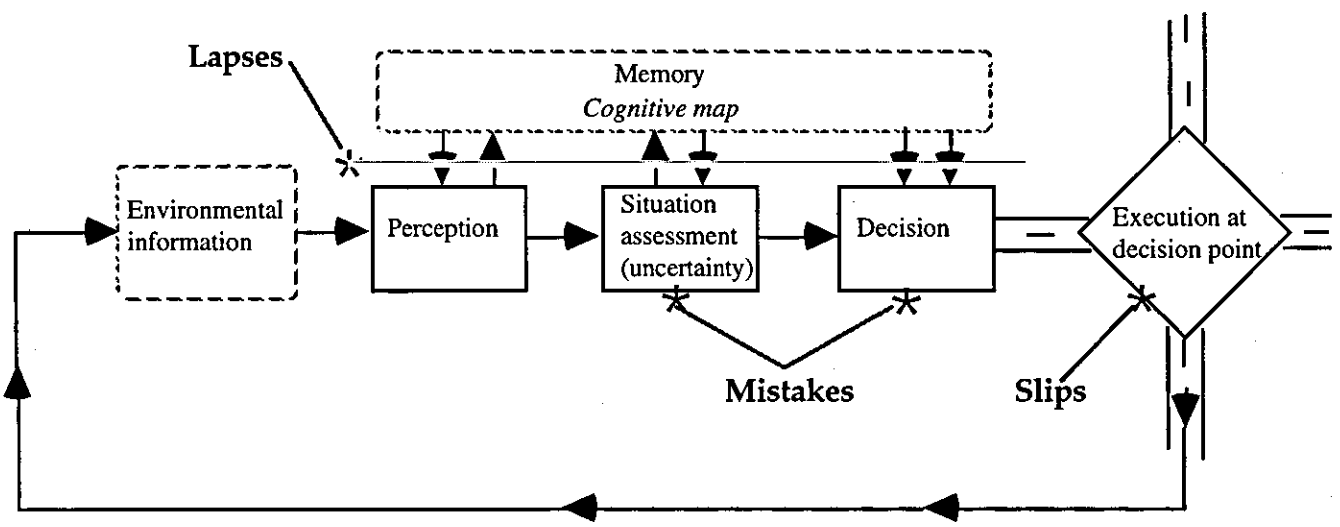


Figure 7.1. Model of Driver Wayfinding with Errors.

driver knows the route because lapses tend to occur in routine tasks (Reason, 1990). However, these same errors would be classified as mistakes if the route was unfamiliar to the driver because mistakes are more likely to occur in novel situations (Reason, 1990). Indeed, Parker et al.'s factor analysis indicated that 'wrong lane at roundabout/junction' loaded on both the mistake factor and the lapse factor. The third error, 'take more usual route by error', can only be a lapse because the route must be familiar for it to happen.

Mistakes occur at the situation assessment and decision making stages of wayfinding (see Figure 7.1). The causes were a) the difficulty of the required decisions, and b) the constraints on information processing. These were the same main factors that emerged in the factor analysis of the wayfinding errors. Previous studies have made similar distinctions among restrictions to task performance. Norman and Bobrow (1975) suggest that performance can be *data-limited* and *resource-limited. Data-limited* describes task performance which is limited by the quality of the data, not by the information processing resources invested (i.e., *resource-limited*). In the context of wayfinding, a data-limited task would represent a situation were the driver requires information, and is capable of applying it, but the necessary information is not available. A resource-limited wayfinding task describes a situation where the information is available to the driver but the high mental workload demands of the task (e.g., driving at speed in heavy rain or traffic on an unfamiliar route) prevents the driver from processing the information. In this case performance is limited by the availability of resources. The next two sections will discuss some specific limitations to data and resources for wayfinding.

Uncertainty

The first cause is linked to the navigational degrees of freedom facing drivers (uncertainty). Uncertainty refers to "... a sense of doubt that blocks or delays action" (Lipshitz & Strauss, 1996, p. 189). People will have more trouble finding their way when the route choices are complex. Consequently, a roundabout with six exits would be more difficult than a roundabout with four exits. Uncertainty is also linked to the quality of the spatial information available to drivers (i.e., data limitations). This information may vary according to its quantity, appropriateness, conspicuity, accuracy and congruity.

Quantity refers to the amount of information that is available; there may be no information to reduce a drivers' uncertainty or plenty of relevant information which eliminates all uncertainty. Insufficient information, in relation to a lack of signs, was the most common reported cause of drivers getting lost in the survey. Obscured signs, another condition of insufficient information, was also a common cause of wayfinding problems. It should be noted that the quantity of spatial information does not necessarily guarantee effective wayfinding. The more information a driver is exposed to, the more information there is that needs to be processed to retrieve the relevant bits. Excessive amounts of information could put constraints on information processing. Therefore, the optimal quantity of information should be set to reduce a driver's uncertainty and not be excessive such that they have to sift through clutter.

The appropriateness of information describes how suitable it is to drivers' needs; for example, distance information may be inappropriate for a driver trying to decide in which direction to turn. The inappropriateness of information was not explicitly listed as a cause of wayfinding problems. The relevance of appropriateness applies to the earlier discussion of information needs. Drivers stated their preferences for different types of route guidance information (e.g., street name, lane position and landmarks). These varied to a certain extent across age, gender, and location. Providing information which is appropriate to the individual driver and situation could improve wayfinding performance.

Cole and Hughes (1988) discuss issues relating to visibility or target conspicuity while driving. Conspicuity is "...the property that leads to a target object having a high probability of being seen within a very short time" (Cole & Hughes, 1988, p . 407). They summarise the following factors that determine conspicuity: eccentricity from line of sight, contrast between target and background, complexity of background, colour and the boldness of information on the target. Obscured signs, which are less conspicuous, were a frequent cause of getting lost reported by respondents in the survey. Conspicuity does not only apply to sign information. It can describe any environmental feature which is relevant to wayfinding; for example, more conspicuous landmarks and path options could make wayfinding easier.

The accuracy of information describes its precision and correctness. A road sign could describe the distance to a village precisely (to the metre) or broadly (to the half mile). Information can also be inaccurate in the sense that it is wrong. Inaccurate directions, in this latter sense, was a common cause of drivers getting lost. Inaccurate information could come from any source of spatial information (e.g., maps, route notes, passenger instructions), although cognitive maps may be particularly prone to certain inaccuracies and distortions (e.g., Tversky, 1992).

The final dimension of the quality of wayfinding information is congruity. This describes how consistent it is with other sources of environmental information, present and past. Incongruous information increases the amount of uncertainty facing a driver. For example, a person would be confused if a sign was directing them to turn left when they were expecting to continue straight. The information from the sign and the driver's cognitive map would be in conflict. In this situation it is uncertain which type or source of environmental information is dominant. The importance of driver expectations was identified in the discussion groups described in Chapter 4. Research should be conducted to determine which sources of information are given priority by drivers.

Constraints on Information Processing

The second general cause of wayfinding mistakes is constraints on drivers' information processing (i.e., resource-limited performance). Wickens (1990) states that information processing can fail in many ways such as limitations on attention, working memory, logical reasoning and decision making. In wayfinding, mistakes would be expected to occur when drivers have insufficient cognitive resources available to make a decision. This may happen when drivers are occupied with the priority of maintaining safe control of the vehicle and do not have sufficient spare attention to devote to a secondary task of wayfinding. Distracted attention (e.g., interaction with a passenger) was the second most common cause of wayfinding problems reported in this study.

Factors which influence wayfinding mistakes can be further categorised in relation to the individual or environment. These factors influence both the uncertainty of the required decisions and the constraints on information processing. Quality of information could vary between individuals as a function of such things as driving experience, and visual, cognitive and spatial abilities. For example, older drivers who have more trouble reading road signs (e.g., Schieber et al., 1994) may have less information to assess situations. Individual differences in the speed and proficiency of decision making would also be important. For example, an inexperienced driver preoccupied with controlling the vehicle may have more trouble wayfinding than a driver with experience. These issues are discussed in the section on individual differences in wayfinding performance (See Section 7.5.7). The next section describes how environmental factors can affect wayfinding performance.

It should be noted that no clear causal attribution to wayfinding errors can be sourced to either the individual or environment. This is a false dichotomy and is only used to organise the description of factors that cause wayfinding problems. In reality, no functional distinction between the individual and environmental causes could be made. This is because the wayfinding task involves an individual person negotiating a route through an environment.

7.5.5. *Environmental Factors Affecting Wayfinding Performance*

Respondents listed two general environmental causes of getting lost: situation and location. Situational variables can have a negative impact on wayfinding performance by reducing the quality of environmental information (i.e., increasing uncertainty) or placing constraints on the capacity to make wayfinding decisions. Three situational variants that can influence this process were identified in this survey: visibility, traffic conditions and time. Poor visibility from bad weather or darkness can obscure environmental information and demand more attention from drivers. Heavy traffic conditions would also require more of drivers' attentional resources and make it harder for them to consider which direction to turn. Time, another situational variant, may also impose constraint on driver information processing. Mistakes would be expected to occur when drivers do not have enough time to make and execute a decision. For example, wayfinding would be more difficult when no advanced warning about a turn is given because, once the driver has spotted the decision point, less time is available to consider route options and execute the manoeuvre. Many respondents in this study reported that badly placed signs had caused them to lose their way (i.e., *saw sign too late to respond*).

The environmental location or context of the wayfinding task also had an influence on wayfinding performance. Specific places that were reported to cause problems were at road repairs and diversions, one-way road systems, large complicated junctions and new road layouts. Locational factors could hamper wayfinding in a variety of ways. For example, road works may be more difficult to negotiate because the signs are temporary and the conditions are less predictable (e.g., narrow lanes and traffic cones). Consequently, while wayfinding through road works, drivers have both inadequate environmental information and constraints on their information processing.

7.5.6. *Guidance Signs*

Road signs are an important source of route guidance information. Route guidance signs (e.g., place names, road numbers, street names, distance signs, direction signs, lane information and road layout signs) provide drivers with information which helps reduce the uncertainty associated with wayfinding decisions. Drivers in the survey and the discussion groups (see Chapter 4) attributed most of their wayfinding problems to signs. They also see improvements to signs as being a focal point for solutions to their problems. The problems with signs were addressed in a specific question in the survey. Respondents suggested a number of changes to improve road signs. The most common suggestions were to have signs which are more frequent, visible, placed sooner, unobstructed, better lit and bigger. With respect to gender differences, female drivers wanted signs to be more frequent than did males. This might relate to gender differences in confidence. Females, because they tend to be less confident in their wayfinding ability (e.g., Devlin & Bernstein, 1995), want more frequent information from signs to reduce their uncertainty to an acceptable level. However, if reduced confidence is related to a demand for more frequent signs, an age difference might be expected such that elderly drivers also wanted more frequent signs. This was not the case. In relation to age differences, younger drivers wanted signs to be more frequent and elderly drivers wanted signs to be less obstructed (e.g., not occluded by vegetation).

It was more common for elderly drivers to complain about signs being obstructed than non-elderly drivers. This might be attributed to age related differences in field dependency. Field dependency describes the ability to visually detect a target from its context background (Ward, Parkes & Crone, 1995). Research has shown that drivers become more field dependent in old age (Ward, Parkes & Crone, 1995). This would make it more difficult for them to see signs on the road side, especially if they are somewhat obstructed by vegetation.

Other research on elderly motorists has identified similar concerns about road signs. Carp (1988), from her survey of elderly motorists, found they reported problems with signs hidden by trees or other obstacles. Research has consistently found that elderly drivers have difficulty with the poor and inconsistent placement of signs (Carp, 1988; Rothe, et al., 1990; Yee, 1985). A small age difference in the preference for better placed signs was found in the present study.

Signs being too small is another problem for elderly drivers (e.g., Rothe, 1990). This was also observed in the group discussions described in Chapter 4. Although size and other visibility issues (e.g., lighting) in signing were identified as problems in the survey, an equal proportion of young and elderly respondents expressed concerns. This would suggest that sign visibility is a problem for all drivers.

It would seem that drivers have many similar concerns across ages about signs. Therefore, improvements to signs should benefit all drivers' wayfinding performance. Although, research has looked at the guidance signing needs of elderly drivers (e.g., McGarry, 1996) much uncertainty remains. There are many ways in which signs can be improved (e.g., (Andre & Segal, 1994). Sign effectiveness can be assessed according to conspicuity, legibility and comprehension distance (Alicandri & Golembiewski, 1994).

Guidelines for signs indicate they must be conspicuous and legible to all types of motorists across all driving conditions (CIE, 1988). Results of this study would suggest these guidelines are not being applied effectively. Most of the suggested improvements to signs reported in the survey can be linked to their conspicuity. It would seem that detecting signs may be as much a problem as being able to read them. The process of reading and responding to a sign requires the sign to be visually detected before the information can be processed and understood (Mace, 1988). Drivers in this study wanted signs to be more visible, bigger and better lit. Research needs to identify ways of improving the conspicuity of guidance signs. The effectiveness of sign designs and placement should be assessed according to Hughs and Cole's (1988) determinants of conspicuity (See Section 7.5.4).

Mace (1988) suggests that driver motivation and expectancy should also be considered in any definition of sign conspicuity. He gives the example of route guidance signs being more conspicuous to drivers motivated to look for them. Cole and Hughes (1988) would describe this as search conspicuity. Mace argues that search conspicuity can be improved by multiple or advanced signing as well as by increases in size, luminance and placement. Results of the survey would support this idea; respondents wanted signs to be more frequent and placed sooner.

The second assessment criterion for signs was legibility distance. Some of the factors which improve sign conspicuity also improve legibility. Respondents in the survey suggested a number of improvements which would increase sign legibility; signs that are bigger, better lit, unobstructed and better maintained. Other features of signs which make them more legible is the message font size and its contrast with the sign background.

According to Mace (1988), elderly drivers require a longer minimum distance to read the information in signs. He attributes this to differences in age related slowing in reaction time, decision making, detection times, and poorer vision. Most the research on ageing and sign legibility looks at symbolic or iconic signs and suggests they are superior for elderly drivers (e.g., Babbitt-Kline, Ghali, Kline, & Brown, 1990). However, it would be difficult to make a symbolic representations of route guidance instructions. For example, it would be a challenge to symbolise the message that Coventry is 20 miles away. One option might be to use symbols to mark popular routes, as with the use of aeroplane symbols to mark routes to an airport.

Sign comprehension, the third assessment criteria, was not as common a concern as legibility and conspicuity. Respondents in the survey expressed a need to have more information on signs (e.g., road numbers and place names). Unfortunately, the amount of information drivers can process from a sign is limited by their amount of exposure to that sign. Exposure would vary with respect to detection time, reading time and familiarity with the sign. Signs can also become difficult to read if they are cluttered with information (Andre & Segal, 1994) or by their close proximity to other signs. Consequently, designers need to carefully consider the quantity and nature of route information on signs and avoid cluttering them with non-essential information (e.g., advertisement).

There are additional criteria for assessing guidance signs beyond the three primary ones discussed above. Those criteria were for assessing the effectiveness of individual signs. They do not consider the effectiveness of signs that are linked to form a system. Route guidance signs also need to have all the right information, be located where decisions are made, and be understood (Arthur & Passini, 1990). The location of route guidance signs is important because they must be close enough to the decision point for drivers to link the sign to the place. Yet drivers complained that direction signs need to appear sooner. Evidently signs need to appear at a sufficient distance to allow drivers the time to make wayfinding decisions. A compromise between these conflicting requirements would be to have redundant signs; a sign before and a sign at the decision point. Confirmatory signs located after a decision point (e.g., a road number; MOT, 1964) would also help wayfinding. They would serve to reduce the uncertainty drivers may have about the success of their last manoeuvre. Furthermore, confirmatory signs would help drivers to detect and correct errors quickly.

Signs should also be mounted and located consistently so that drivers know where to look. This would reduce the time required to detect them. Lastly, signs need to have better continuity along a route. One of the main limitations of signs reported by the respondents was that they were not frequent enough. Lack of signs was the most common cause of wayfinding problems reported in this study.

7.5.7. *Individual Factors Affecting Wayfinding Performance*

The general pattern of causes of wayfinding problems was similar across gender, although more female drivers blamed errors or themselves than male drivers. In terms of age differences, younger drivers blame themselves (e.g., inattention), signs and errors (e.g., missing a turn) more than elderly drivers. Elderly drivers blamed locations (e.g., cities) and situations (e.g., night time) more than younger drivers. These age differences in causes of getting lost must be linked to general driving difficulties. Elderly drivers seem to report wayfinding problems in locations and situations, particularly ones they prefer to avoid (e.g., heavy traffic). This is understandable considering that anything which makes driving difficult for a person would also make wayfinding difficult. The younger drivers may experience fewer wayfinding problems in these particular locations and situations because they find driving less difficult. It is important to note the main cause of getting lost, irrespective of age and gender, was problems with route guidance signs.

The hypothesised model depicting the relationship among driver's individual characteristics and wayfinding problems did not provide a good fit to the data (see Figure 6.43). Although most of the proposed relationships among the variables were significant and they explained a significant proportion of variance in wayfinding problems (52%), the LISREL analysis indicated the model did not describe the data.

There are a number of explanations for the model's poor fit to the data. Perhaps it does not accurately describe the relationship between drivers' individual characteristics and wayfinding problems. Limitations in the model might be caused by the absence of important paths. For example, there may be a link between vision and poor health. There could also be some important variables that were dropped from the model because they could not be easily measured by postal questionnaire (e.g., attentional skills and decision making ability; See Figure 3.3). The inclusion of these variables may have improved the model's fit. Alternatively, the assumption the model was fully recursive may be wrong. Some of the relationships may have been reciprocal; for example, experience and confidence may well be inter-related.

There are some other explanations for why the model of drivers' individual characteristics and wayfinding problems did not fit the data. The variable measures may have been unreliable such that they were prone to error. Indeed, the internal reliability of the health measure was not high. Poor construct validity among the variables is a plausible explanation for why the model did not fit the data. With the exception of age and gender, it is uncertain whether the measures truly represent what was intended. For example, the five items that constituted the *poor health* measure may not have provided an accurate representation of respondents' health. The absence of significant correlations among some of the variables would support this explanation. Thus, the model may be correct but it does not fit the data because some of the measures do not accurately portray the true variables. Many of the relationships among variables were significant. All the path correlations were significant; with the exception of experience with confidence, and poor health with wayfinding problems. Future research should attempt to explore the relationship between individual characteristics and wayfinding problems with an emphasis on the construct validity of the measures. A laboratory based experiment might also provide a better opportunity to measure all the individual characteristics described in Figure 3.3. This might provide a clearer understanding of the relationship of age to wayfinding problems.

7.5.8. Consequences of Getting Lost

Drivers were given a set of positive and negative adjectives to describe their feelings when lost. Drivers reported predominantly negative feelings when lost. This is further evidence highlighting the consequences of wayfinding problems. The most common feelings, irrespective of age or gender, were irritation and frustration. Elderly drivers reported feeling more embarrassed and foolish than younger drivers and more younger drivers reported feeling frustrated and irritated. Females reported feeling anxious when lost and more males reported feeling embarrassed.

It is uncertain why there were differences in emotional responses between these groups of drivers. They may relate to age variations in driving tasks because most of the travel younger drivers did related to work and this was not the case for elderly drivers. Perhaps the younger drivers were more concerned with the wasted time and inefficiency caused by wayfinding problems and their implications for work. These concerns may be more likely to spawn feelings of irritation and frustration. Driving for other activities like recreation, shopping and socialising may involve fewer time constraints. Efficiency and punctuality would be less important when driving for these activities. Consequently, more elderly drivers report feeling foolish and embarrassed because they are considering their driving performance rather than some external concern.

7.6. Mobility and Wayfinding Problems

One of the aims of this research was to determine whether wayfinding problems had an impact on driver mobility. Results indicate wayfinding problems do indeed have a negative impact on mobility. This occurs even when controlling for standard predictors of mobility (age, gender, employment, health, fitness, and costs of driving). Similar results occurred for three different measures of mobility (weekly mileage, weekly number of trips, and average driving frequency for non-work activities).

Mobility was defined in Chapter 2 as the ability to travel independently and conveniently. There are objective and subjective components to this definition. This research only considered the objective component of mobility (i.e., actual distance and frequency of travel). The qualities of mobility in terms of independence and convenience were not assessed. Neither was subjects' perceived ability to travel independently and conveniently. Although it is clear that wayfinding problems reduce mobility in terms of the amount of driving, it is uncertain whether they infringe on the quality of this mobility. For example, wayfinding problems could restrict drivers' experiences of new places and their associated activities. The relationship between wayfinding problems to these subjective aspects of mobility need to be investigated. It seems reasonable to posit that wayfinding problems would have an equivalent impact on peoples' ability to fulfil their needs by driving as they have on their amount of driving.

Health and costs of driving were the only covariates in the analysis that did not significantly predict at least one of the three mobility measures. According to Carp's (1971) survey, economic status was the most important factor in determining whether retired people drove (see Chapter 2). It also had a large influence on the destination and frequency of their trips, and their ability to meet their needs through driving. Results of this survey did not support Carp's findings. The ability to afford the expenses of driving did not significantly contribute to the prediction of mobility. Perhaps a relationship between mobility and financial status might have been found if a more general measure of economic status had been taken. There are many factors related to economic status (e.g., education, age and employment). Perhaps it is these factors which are directly related to mobility and not the specific ability to meet the expenses of driving. An alternative explanation is the absence of a relationship between the ability to afford driving and mobility may be linked to the survey sample. Since all respondents in the survey had regular access to a car they could afford to drive (i.e., variance restriction). People who could not afford to drive were not surveyed.

Previous research has also found a relationship between health and mobility. Drivers who consider themselves to be in poor health restrict their driving frequency and distances they drive (AA, 1988; Carp, 1971; Marottoli et al., 1993; Rabbitt et al., 1996; Schlag, 1993). The most plausible explanation for a lack of relationship between health and mobility in the present study is that the validity of the health measure was not high. Indeed, similar problems with the health measure occurred in the model of individual differences in wayfinding performance.

7.7. Solutions to Wayfinding Problems

This survey provided evidence indicating that wayfinding problems have a negative impact on mobility. This is a significant finding considering that any threat to driver mobility is serious given people's heavy dependence on cars. The effect wayfinding problems have on mobility is also concerning given its link to independence and well-being. Solutions for how to reduce wayfinding problems should therefore enhance driver mobility. These solutions will also reduce the irritation and frustration expressed by drivers who have problems wayfinding. The remainder of this chapter discusses some potential solutions to wayfinding problems.

In consideration of the model of driver wayfinding errors (see Figure 7.1), there are a range of potential solutions. If mistakes are the product of high uncertainty (data-limited) and constraints on driver information processing (resource-limited), then solutions will have to reduce this uncertainty and minimise the constraints. Not much can realistically be done to change the road environment or the driver, although perhaps drivers could be trained to improve their navigation strategies and compensate for any individual limitations. For example, drivers could learn to avoid situations like heavy traffic or night-time when they find wayfinding difficult. However, they are probably already aware of their limitations and are naturally inclined to avoid these situations. Alternatively, drivers could be trained to invest more effort in route planning. Elderly drivers, who tended to report more wayfinding difficulties, might be trained to modify their planning and wayfinding strategies to accommodate for specific age-related declines in their ability. Elderly drivers reported they did not change their strategies as they got older. However, those strategies which served them well as young drivers may no longer be appropriate in old age. Elderly drivers could be made more aware of their limitations with respect to wayfinding (e.g., reduced visual processing speed). Making more thorough route plans and travelling with a passenger are two ways that could reduce some of their difficulties. It is doubtful that these options would appeal to motorists because they impose restrictions on mobility and demand more preparation time and effort. Nevertheless, training programmes have been shown to have a beneficial influence on elderly drivers' performance using an in-vehicle information system (Simoes, 1996).

There are three general changes to the road environment that might assist driver wayfinding: reducing the complexity of the road geometry, making the road network more consistent, and improving signage. The first two solutions are somewhat impractical because the existing road network could not be easily changed. Where possible, civil engineers could simplify wayfinding by designing future roads using predictable configurations. This should help drivers as cities laid out in a grid configuration facilitate spatial knowledge (Evans et al., 1984). Inconsistencies or anomalous situations within the road system also cause wayfinding problems for drivers. These problems occur because information in the environment contradicts driver expectations (i.e., their cognitive schema; see Chapter 3). Encouraging greater standardisation in the road system should reduce some of the difficulties caused by inaccurate driver expectations. For example, if street signs were standardised for size and location, drivers would know where and what to look for.

The most promising solution to driver wayfinding problems will probably consist of improvements to road signs to support accurate situation assessment and decision making. Signs provide drivers with information which helps reduce the uncertainty associated with wayfinding decisions. Signs were blamed most frequently for wayfinding difficulties. Common problems with signs were: lack of signs, obscured signs, badly placed signs, insufficient information on signs, damaged signs and confusing signs. Signs need to be more conspicuous, easier to understand and legible from a further distance. Legibility can be improved with better sign fonts, for example *clearview* font has better night-time legibility and a longer recognition distance (Garvey & Pietrucha, 1996). Other improvements are to have more continuity along a route and ensure that signs are better maintained.

Elderly and female respondents rated their map reading abilities as being less than that of other drivers. They also reported map reading to be a more difficult task than did other drivers. Training drivers to read maps and improving map design may also help them with their wayfinding and route planning. It has been suggested that map reading skills among the general population are low (Williamson & McGuinness, 1990). Perhaps map reading and route planning could be introduced into the curriculum of driver training. It could also be offered in refresher courses targeted at elderly drivers (e.g., 55 Alive and RoadFit). However, as mentioned earlier, training may be a less effective solution because it could be considered an inconvenience by drivers.

Improving the design of road maps could also assist driver route planning and wayfinding. For example, Bell (1997) has suggested that route knowledge acquisition could be improved with segmented strip maps. Computerised maps (e.g., AutoRoute) might be an effective method of simplifying route planning. A driver could enter the starting point and a destination name and the route would appear highlighted on the map. This would eliminate the processes of having to locate the position of the starting and end points on the map. It would also identify and select the various path options for drivers. In-vehicle electronic moving map displays are another option that might assist driver wayfinding. They can simplify the map reading task by constantly updating a driver's progress along a route and by providing an ego centred reference frame (i.e., the road ahead is up on the map). The effectiveness of different map orientations (north up vs track up) varies with map reading task (Prabhu et al., 1996). It is not recommended that moving map displays be employed as a primary source of information in guidance systems because of their potential for dangerous distraction. However, they impose no risk as a source of map information when the vehicle is stopped. More research needs to be conducted to identify ways in which road maps, both conventional and computer based, can be improved to assist driver wayfinding.

In-vehicle route guidance systems may also offer solutions to wayfinding problems. This technology, which has been specifically designed to assist wayfinding, could aid the process at different levels. It could help reduce uncertainty by providing information which is not available to drivers or by supplementing environmental information. For example, the system could tell the driver how far it is to the next turn. Route guidance systems could make information more accessible by displaying it clearly in the vehicle where drivers know where to look. Furthermore, it could be displayed sooner before the decision point and for a longer period of time giving drivers more time to assess the information and the ability to read it at their convenience. Another benefit is that the systems can display information using sound instead of vision. This could potentially reduce the demands on drivers' visual resources because they would have less need to search visually for the necessary environmental information.

With respect to the decision making stage of wayfinding, route guidance systems make many decisions for the driver. The system would give drivers the direction and location of each manoeuvre. They would then match the instructions or decisions to a location in their forward view and execute the manoeuvres. Route guidance systems could also help direct drivers along routes which are easier to negotiate. They could select routes which have fewer and less complex decision points. And, if the systems were linked to a traffic control network, they could re-direct drivers to avoid heavy traffic conditions. These features might be particularly beneficial to elderly drivers who prefer to avoid these driving situations.

Despite the many potential benefits of route guidance systems, there are also some serious limitations. The most significant limitation is the impact these systems will have on driver safety. Their introduction in cars may place more demands on drivers and interfere with the safe operation of the vehicle. Indeed, research has shown that route guidance systems do distract drivers' visual attention away from the road ahead (e.g., Wierwille, 1993 and See Chapter 8). If drivers cannot find their way safely with route guidance systems then there will be no benefit accrued from this technology. The safety of these systems will have to be thoroughly assessed before they are installed. The next chapter investigates the use of in-vehicle route guidance information as a potential tool to reducing wayfinding problems.

7.8. Chapter Conclusions

This chapter discussed the results of the questionnaire survey of navigation and driving. Respondents' driving activities were consistent with the literature. People drove less with increasing old age. This trend also applied to unfamiliar routes. Routes were most commonly planned by reading maps, making route notes and asking someone for the information. These strategies did not differ substantially across road environments, gender or age. Elderly and female respondents tended to rate lower spatial abilities and map reading abilities than did the male and non-elderly respondents.

Wayfinding strategies conformed with the planning strategies. For unfamiliar trips on major roads, drivers relied on their memory and/or referred to maps or notes of the route. For unfamiliar trips within a city, drivers would stop to ask for directions or read a street map. Elderly drivers relied less on their memory than did the non-elderly drivers. This difference is believed to reflect an attempt to compensate for the age related decline in their ability to recall routes. In terms of the specific information needs for wayfinding on major roads, drivers stated a preference for road number, place name, and junction information. In cities, they requested information about street names, lane position and landmarks. More non-elderly (< 60 years of age) and female drivers expressed a preference for landmark information. The importance of route guidance that is adaptable to different users and road environments is highlighted by these findings.

A theoretical model of wayfinding classifies wayfinding errors as mistakes which are caused by uncertainty and constraints on driver decision making. Mistakes occur when the quality of spatial information and/or the available processing resources are insufficient to make correct wayfinding decisions. Variations in the quality of spatial information and driver information processing resources were described according to the environment (e.g., road signs) and individual (e.g., age).

The proposed model of the individual factors affecting wayfinding performance did not accurately describe relationships within the data, although it could significantly predict wayfinding performance. Limitations of the proposed model were attributed to missing variables and path links, as well as some potential problems with the reliability of some of the measures.

As hypothesised, elderly drivers reported more difficulties with navigation and these problems were found to reduce driving mobility.

However, it should be noted that these relationships are not uniform amongst the population of elderly drivers. They represent the average performance across an extremely variable group of people. Consequently, although the effects of ageing on navigation performance are generally negative, there are elderly drivers who are highly skilled at navigation. Furthermore, there are non-elderly drivers who are poor navigators.

A number of solutions were proposed to reduce navigation problems. These included recommendations for improvements to road signs, driver training and the use of in-vehicle route guidance systems.

Chapter 8: Presentation of Route Guidance Information

8.1. Chapter Summary

This chapter describes a study conducted in a driving simulator of the presentation of route guidance information. A review of research indicates there has been no comparison of the effectiveness of route guidance displays using speech only or speech supplemented with visual information. A study is conducted to investigate the safety and efficiency of visual, auditory (speech) or a combined visual-auditory display for presenting route guidance information. Driver performance, visual behaviour, subjective mental workload and preferences were recorded. Subjective mental workload for the visual only condition was rated significantly higher than the auditory and combined visual-auditory conditions. Visual behaviour measures indicated the visual only display was most attentionally demanding (or distracting). The majority of participants preferred the combined display format followed by the auditory only display. Most wayfinding errors occurred with the visual only display. The same relative conclusions regarding display performance applied to both non-elderly and elderly participants. Recommendations for how to present simple route guidance information are discussed.

8.2. Introduction

For wayfinding, drivers conventionally rely on memory from studying the route earlier and/or refer to maps or notes of the route (see Chapters 6 and 7). In-vehicle route guidance has been developed to supply drivers with the information necessary to make car travel more efficient, wayfinding easier and driving safer (CEC, 1991). The information is intended to assist drivers in selecting the appropriate manoeuvre when faced with a wayfinding decision. Many different in-vehicle guidance systems have been developed or are currently being developed. Guidance is just one category of route information that can be provided by these in-vehicle systems. Route information has been subdivided into three categories: route planning, route navigation and route guidance (Ashby & Parkes, 1993). Route planning, which is done before a trip begins, might require information about route options, weather conditions, traffic patterns, and availability of service facilities. With route navigation, drivers are given details about the road network and are left in control of route decisions. Ashby and Parkes (1993) describe route guidance as being real-time in-transit route information that guides drivers through each manoeuvre to a destination.

There are a number of possible benefits of route guidance systems (van Winsum, 1993). They could reduce travel time, distance driven and help drivers avoid congested routes. Route guidance could also reduce the number of drivers getting lost and have a potential to improve road safety (van Winsum, 1993). In-vehicle route guidance could improve road safety by reducing demands on drivers when travelling in an unfamiliar area. Driving in an unfamiliar area requires more attention to driving in a familiar area. The task of controlling and manoeuvring the vehicle becomes more demanding because drivers do not know what to expect. Furthermore, additional attention is needed to scan the environment for navigation information that is not already available from experience. These increased demands associated with the traditional process of navigating a car in an unfamiliar environment may also increase the risk of collision (e.g., Rothe et al., 1990). Route guidance systems could lower these demands by reducing drivers' need to actively search for wayfinding information.

In addition to the general driving population, there are certain professions that could benefit greatly from route guidance systems. Route guidance would be beneficial to most professions that rely heavily on transportation, for example: taxi drivers, delivery services, the police and emergency services. In these professions people are frequently required to drive to different and unfamiliar destinations quickly. The information made available through route guidance systems would be an asset to any of these professions.

Tourists would also benefit from route navigation. Tourists by nature tend to drive in unfamiliar areas and may benefit from navigation assistance. The need for in-vehicle navigation information in tourism has already being identified. Vehicle manufactures have installed route navigation systems in rental cars (Andre, Hancock, & Smith, 1993).

In-vehicle route guidance systems could also be a solution to the navigation problems of elderly drivers (see Chapters 4-7). The limitations of traditional sources of route guidance information (e.g., signs) would be avoided with these in-vehicle systems. However, these route guidance systems may also have potential limitations, especially with respect to elderly users.

Route guidance is just one of a variety of in-vehicle systems that will be available in future vehicles. Existing or prototype technologies include: collision avoidance systems, driver status monitoring, radio data systems, vision enhancement, and breakdown detection systems. The technology, generally referred to as Intelligent Transport Systems (ITS), has a common problem across all its sub-systems. The problem is ITS was, and is being, created primarily with the motivation to create applications for new technology (Owens et al., 1993). This technology driven approach to design gives little consideration to the characteristics and needs of users. Unfortunately, the potential benefits ITS has for elderly drivers may not be actualised because it was not developed with elderly users in mind (Sixsmith & Sixsmith, 1993).

Failure to consider the characteristics and needs of all user groups raises concern because the technology may impede instead of assist driving. ITS will most likely overload the driving task by increasing the amount of information that has to be identified, perceived and responded to (Stamatiadis, 1993). Increasing complexity of the driving task will create problems for all drivers but may have a more serious impact on elderly drivers. The same characteristics of elderly drivers that ITS could assist will create barriers between elderly drivers and their ability to use the systems effectively. Thus they may become worse off if systems are not designed to take account of their particular requirements. Elderly drivers, with their reduced physical and information processing abilities, may become overloaded on an already difficult and complicated task by the additional demands of ITS (Stamatiadis, 1993). Information needs differ across ages and gender (see Chapter 7) so route guidance should be flexible so as to present different sets of information depending on the type of user and users' preferences.

The purpose of in-vehicle route guidance systems is to safely present drivers with the information necessary to make wayfinding decisions. There are two main criteria that can be used to evaluate performance of these systems. They can be evaluated with respect to navigational effectiveness or in terms of their safety. Safety should be the primary concern. If in-vehicle route guidance systems cannot be used by all drivers safely then they should not be installed in cars. The secondary criterion of wayfinding effectiveness is not independent of safety. Wayfinding effectiveness refers to the ease and efficiency with which a person travels to their destination. This will be reduced if drivers take excessive risks in the process. For example, if route guidance information is difficult to follow then it will likely be more demanding and would interfere with safe driving.

There are many uncertainties concerning what information drivers need in order to navigate (Ashby & Parkes, 1993). For example, how detailed should the information be that is displayed to the driver? There are also many uncertainties about the safest and most effective method of presenting navigation information to drivers (Ashby & Parkes, 1993). For example, should it be passively displayed on a map or should drivers be actively informed by a voice instruction? The method of displaying route guidance information is a fundamental issue in designing these systems. There are essentially four media for presenting route guidance information: text, symbols, speech and maps (Ashby & Parkes, 1993). These methods can be employed alone or in combination. For example, navigation instructions could be given solely by map display or with printed text to accompany the map. There are advantages and disadvantages, in relation to safety and navigational performance, with each display method. Furthermore, the type of information required (i.e., most suitable for task and driver) is linked to the display format. For example, if drivers need configurational information, logic would dictate a visual map display. This relationship between navigation information and display format is discussed later in this section.

One of the first studies to compare the effectiveness of various in-vehicle navigational displays was conducted by Streeter et al. (1985). They compared four different types of navigation: verbal directions, paper based customised route map, verbal instructions combined with a customised route map, and conventional paper maps (control group). The verbal directions consisted of detailed pre-recorded messages that were played on demand by subjects and could be repeated. They were recorded by a female speaker. These messages provided information about distance between turns, location of turn, turn direction, as well as information about approaching turns, and errors.

The customised route map displayed roads with four different colours (Streeter et al, 1985). These maps were drawn to scale and provided the same information as the verbal instructions. The control group were given conventional road maps and the address of the destination. They were told to use whatever other means of navigation they would normally rely upon when driving alone (e.g., asking local people). The 57 subjects of unreported age drove on three different routes using one of the four methods of route guidance. The dependent measures were: time to complete the route, distance driven, number of turns, number of repeats of recorded instructions, number of referrals to the map, number and type of navigational errors.

Subjects were found to have travelled the shortest distance in the verbal instructions condition. The fastest completion times were also found in the verbal instructions condition. Of the experimental conditions, most navigational errors were committed in the map alone condition and fewest errors were committed by subjects receiving only verbal instructions. In terms of subject preference ratings, it was found overall that most preferred verbal instructions. A complaint was that verbal directions did not provide an overview of the route. Streeter et al. (1985) concluded from this research that route guidance systems should be voice oriented given their superiority over maps. Unfortunately, they did not look directly at the safety of each type of display.

The superiority of verbal route guidance over conventional maps was also demonstrated in a study by van Winsum (1987). Simple verbal left or right turn instructions were compared to a map display of route information. Effectiveness of the two route guidance displays was evaluated in terms of navigational errors. The average number of errors committed in the map condition was 2.2 whereas no errors were committed when verbal instructions were given. The errors in the map condition were mainly attributed to subjects' difficulty in keeping track of their position on the map. This study also failed to evaluate the safety risks of the two display formats.

Problems of keeping track of one's position on a map while in transit could be alleviated by CRT type moving map displays that change according to vehicle position. Wierwille, Antin, Dingus, and Hulse (1988) compared performance of three different types of route navigation displays: memorised route, conventional paper map, and a CRT-drawn map (ETAK) of the roadway network. This is only relevant to the research in this chapter because of their experimental design. The systems evaluated were for navigation only and not guidance; drivers had to make their own route choices from a map and were not given specific wayfinding instructions. They had 32 drivers of both gender aged 18 to 73 with a wide range of driving experience drive three different routes. The number of elderly subjects was not mentioned. These routes had a variety of different road conditions. Subjects were counterbalanced by route and method of navigation so every subject used each method of navigation and drove on all three routes. Navigation performance was also assessed in relation to spatial ability, age, driving experience, traffic density, and road type. Navigational effectiveness was rated by an experimenter on a scale of 1 to 5; where 1 meant the subject got lost and 5 meant the subject had no problem finding the destination. Trip duration was measured to assess navigational performance. Visual glance measures were taken in an attempt to assess visual scan patterns relating to each method of navigation.

Visual demands in driving are an important concern because vision is the primary source of information while driving. Vision is a single resource that can only gather information from one location at a time (Wierwille, 1993). While driving a person must watch the road ahead, check mirrors, and monitor the instrument panel. Watching the road is a priority because it provides information required to guide the car and detect hazards (Wierwille, 1993). Reduction of visual attention to the roadway ahead increases the risk of missing information critical to safe driving. Anything distracting visual attention to this information can be unsafe.

Visual glance data provides a measure of distraction of visual attention from the primary task to other tasks like an in-vehicle route guidance display. It is typically measured by recording drivers' eye movements. Visual attention is described in terms of location, duration and frequency of glances. Fairclough, Ashby and Parkes (1993) suggest glance duration is sensitive to the complexity of a display, whereas glance frequency represents the amount of visual activity.

Designers have simplified route guidance displays in an attempt to decrease visual demands. These displays use simple direction arrows to indicate which way to turn instead of maps. In another study of in-vehicle route guidance displays, Verwey & Janssen (1988) compared the effectiveness of navigating by direction symbols, memorised map, and verbal instructions. Wayfinding performance was the dependent measure. Significant differences were found for number of errors committed among the three conditions. Subjects receiving verbal directions alone committed the fewest errors, followed by those given directional symbols. Most errors were committed by drivers navigating by memorised map. Verwey and Janssen (1988) only examined navigational performance in terms of its effectiveness in guiding drivers to their destination. Their results in this sense are consistent with Streeter et al. (1985) and van Winsum (1987) in finding that verbal directions were the most effective form of displaying route guidance information. They did not examine the relative safety of using the three types of information displays.

Labiale (1989) also compared the performance of three different methods of displaying in-vehicle route guidance information: electronic map alone, map with auditory information, and map with written information. The electronic map was displayed on a video screen mounted on the dashboard at steering wheel height and tilted toward the driver. Two maps varying in their information content were used in this study. Text instructions were displayed below the maps and the auditory display was the same text being read. Specific details about the content and timing of messages were not provided.

Sixty drivers, aged 20 to 63, participated in Labiale's (1989) study. Comparisons were made on two routes of varying complexity (1 to 3 changes in direction). The dependent measures taken were visual glance data, route recall performance, preferences, and steering and speed variability. Labiale found the least amount of glancing was at maps that were supported with verbal directions. Glance duration increased with map complexity. Drivers were reported to prefer maps with verbal directions. Route recall was best for maps with text directions. With respect to glance duration, maps presented with verbal directions was the safest way of presenting route guidance information.

Schraagen (1990) compared three types of route guidance instructions presented on cards to 42 drivers. Subjects were shown cards with direction arrows on them, a single printed instruction referring to road signs, or a series of printed instructions. Subjects used each method of display on three different routes. Fewest navigational errors occurred with directional arrows. The multiple instruction condition had most navigational errors, highest subjective workload estimate, attracted most glances, had subjects paying less attention to other traffic, and were judged to be the least clear of the instructions.

In another study, Fairclough et al. (1993) compared paper map route guidance displays to LCD displayed text instructions. A detailed map was attached to the instrument panel of the experimental vehicle. The route was highlighted in green and the map could be rotated around its centre point. This was intended to allow subjects to orient the map as desired. The text instructions were presented in a list with the current instruction highlighted on a LCD screen. They used 20 drivers of both gender aged 20 to 60 with a wide range of driving experience drive two different routes using both methods of guidance. The order of route and condition were counterbalanced. Subjects were unfamiliar with the routes. The dependent measure examined in this study was visual behaviour measured by three cameras directed forward to the road, right-side and driver's face. They found there was an increase in visual attention (percentage of time) to the paper map and a decrease in attention to other areas of the driving environment. The paper map also required more visual attention than text instructions.

Finally, in a study by Burnett and Parkes (1993) comparisons were made between performance with a route guidance system displaying directional symbols alone with one that also displays them with verbal instructions. Directional symbols were displayed on a LCD screen mounted on the centre of the dashboard at steering wheel height. Three types of direction symbols were used: straight ahead, a turn arrow presented 100 yards in advance of the required manoeuvre, and a turn arrow accompanied with distance to the manoeuvre. The verbal instructions were a digitised male voice.

There were 16 subjects in the Burnett and Parkes (1993) study, aged mostly under 30 and split equally between both sexes. Subjects drove two routes using the visual only route guidance on one and the visual plus verbal directions on the other. This was counterbalanced along with the types of symbol presentation. Dependent measures were time to complete route, number of navigational errors, visual glance data, subjective workload, and preferences. Results showed glances were more frequent and lasted longer for the visual direction symbols. Glances were also more frequent and lasted longer when no information was given about distance to the next manoeuvre. There was no difference in number of navigational errors committed across conditions. Directional symbols supported with verbal instructions were perceived to be less stressful and easier to use than directional symbols alone. Subjects were reported to prefer the two sources of route guidance information rather than direction symbols alone. They also preferred distance to next turn information.

Research on in-vehicle route guidance and navigation has given some consideration to the elderly driver. Wierwille et al. (1988) compared the visual attentional demand requirements of route navigation systems. They found subjects over 50 years of age took longer to complete the navigation tasks, looked at the navigation displays and instrument panel longer, and made a greater number of errors than younger subjects. Wierwille (1990), in a summary paper of his earlier research on the effects of age on instrument panel performance, reports elderly drivers consistently require more glance time to complete in-car tasks. Furthermore, elderly drivers take more time to switch visual attention between tasks.

Walker et al. (1991) evaluated seven different types of route guidance in a driving simulator. The sample consisted of 126 drivers grouped as young (mean age = 23), middle (mean age = 38) and older (mean age = 63). Dependent measures were wayfinding performance, heart rate variability, speed, lane keeping and reaction time on a secondary task. The control guidance condition was a paper strip map of the route. There were three visual displays of different complexities. The most complex display consisted of a moving map. The least complex display used turn arrows and the medium visual guidance display used text with direction arrows. Three auditory displays were designed to parallel the visual displays. Fewest wayfinding errors occurred with the simple auditory display. The complex visual display was considered to be the most unsafe. Elderly drivers were judged to drive less safely (i.e., more lane variability, longer reaction time) and committed more wayfinding errors than the younger groups.

Marin-Lamellet, Chanut and Pauzié (1993) investigated age-related effects of dividing attention between a simple computerised tracking task and the identification of direction symbols. They intended to make inferences about route guidance systems from the results of this research. No age differences in performance for directional symbol size, screen position, contrast type and value, and mistakes were found. Elderly subjects performed worse than younger subjects on the tracking task.

The results of Marin-Lamellet et al. (1993) are surprising considering the evidence for age related declines in contrast sensitivity, visual acuity and attention switching (see Chapter 3). However, their experimental design was not particularly conducive to finding any significant age effects. Their sample of old subjects were perhaps too young (mean age 58.5 years) to demonstrate any notable decline in performance. Also, the fact elderly subjects showed poorer performance on the tracking task may suggest strategy differences. For example, they were trying to perform better on the secondary signal detection task at the expense of performance on the primary tracking task. Furthermore, the features (size, contrast and position) of the target symbols may not have been sufficiently extreme to distinguish age effects.

Barham et al. (1993) studied navigation and driving performance of 35 elderly drivers (65 years) using an electronic map based route guidance system (TravelPilot). They assessed driving performance with and without the route navigation system. Driving performance was evaluated by a driving assessor seated adjacent to the driver. Visual demands of the navigation system were measured by another observer seated in the rear of the vehicle. They reported that electronic route guidance maps did not create any safety related problems for elderly drivers and that age was not related to performance. Limitations in their research design reduces the validity of their conclusions. They did not counterbalance the experimental trials; all subjects first drove without the route guidance system then with the system. Thus any improvement in performance with the route guidance system could be attributed to learning effects from driving the test vehicle. Not all subjects drove the same routes making it difficult to compare them. Furthermore, they have no basis of comparison to assess the relationship between age and performance because only elderly drivers were examined. They can only report there are no age differences in performance amongst drivers over 65. No data were reported to compare glance behaviour while driving with and without route guidance. The accuracy of recording visual glance behaviour by an observer as it occurs has questionable validity. Consequently, they could not reliably conclude that a map based guidance system was safe for elderly drivers.

Pauzie and Anadon (1993) compared wayfinding performance with guidance from directional arrows combined with preparatory beeps or verbal instructions. They had ten elderly (mean age = 60) and ten young subjects (mean age = 26) drive a route in a fixed based simulator with a video projected roadway. Dependent measures were visual behaviour and subjective preferences. Elderly drivers had higher glance frequencies toward the visual display than younger drivers. The auditory beeps used to inform drivers of impending directions were considered to be annoying. Subjects often considered verbal information to be sufficient and did not glance at the visual display. Despite not having tested verbal only guidance, Pauzie and Anadon concluded a combined verbal-visual display was optimal because vehicle noise might be problematic for speech only guidance.

Currently, the focus in research and design trends seem to prefer the use of directional symbols supported with verbal instructions for displaying in-vehicle route guidance information. This redundant use of directional symbols and verbal instructions most likely reflects an attempt to overcome the limitations of both the visual and auditory displays. This approach appears to have been motivated by the assumption that modal redundancy in this situation is superior to a single mode of presenting information. However, this assumption has not been tested.

Leiser (1993) describes some of the advantages and disadvantages of using speech information in vehicles. Speech is most advantageous when visual resources are overloaded. Driving is an ideal situation for speech presentation of information because it has heavy visual demands and low demand on the driver's hearing. One problem is that speech is transitory rather than continuous and must be repeated if the driver does not hear it first time. Another problem is that speech cannot be scanned for relevant information as easily as visual displays and drivers must listen to the whole message. Social norms also create problems for speech displays because people have learned to listen and not interrupt when they are being spoken to. Speech is also vulnerable to background noise problems and elderly people experience more trouble hearing (see Chapter 2).

An advantage with visual displays is they can be displayed continuously and people can refer to them at their convenience (Leiser, 1993). Also, in accordance to stimulus-response compatibility theory, spatial responses like navigation and driving are most compatible to a visual stimulus or display (Wickens, 1990). This is particularly important for elderly people who are more vulnerable to stimulus-response incompatibility (Charness & Bosman, 1990). A difficulty for visual displays is that they are more prone to problems such as glare, poor contrast, and low illumination. These problems need emphasis because elderly drivers tend to have reduced visual function.

It is clear from descriptions of the advantages and disadvantages of verbal and visual displays, they could indeed complement one another. However, no research has been conducted to determine whether there is actually an increase in navigational performance and safety by presenting directional symbols and verbal instructions together. Verbal information alone may be sufficient to guide drivers along their route.

Research has failed to adequately address some of the issues described herein. This failure can most likely be attributed to its origins. Much of it has been conducted to evaluate in-vehicle route guidance systems that are in existence or being developed (e.g., Barham et al., 1993; Fairclough et al., 1993; Wierwille et al., 1988). This consultancy research is less able to manipulate how navigation or guidance information is presented because systems in production are being evaluated and do not have the flexibility. This method is flawed since it cannot identify ideal configurations for in-vehicle route guidance systems, it can only demonstrate relative superiority. Furthermore, studies comparing route guidance with route navigation are biased because they represent different tasks. Selecting a route from a moving-map display (navigation) is not the same as following a pre-determined route (guidance). Consequently, the superiority of one system or display format over another in terms of safety and wayfinding efficiency is not being fairly assessed. Similarly, studies have attempted to assess the effectiveness of visual and auditory modalities while displaying different information. This prevents any conclusions being drawn about the merits of either information type or modality. One source of variability must be held constant to eliminate potential confounds.

Table 8.1. Research on route guidance display methods.

Study	Auditory	Visual		Auditory & Visual	
	Speech	Maps	Symbols	Speech & maps	Speech and symbols
Streeter et al. (1985)	✔	✔		✔	
van Winsum (1987)	✔	✔			
Wierwille et al. (1988)		✔			
Verwey & Janssen (1988)	✔		✔		
Labiale (1989)		✔		✔	
Schraagen (1990)			✔		
Walker et al. (1991)	✔	✔	✔		
Fairclough et al. (1993)		✔			✔
Pauzie & Anadon (1993)					✔
Burnett & Parkes (1993			✔		✔
This Chapter	✔		✔		✔

There are many different types of route guidance information and a number of ways to present this information to drivers. One of the simplest bits of information drivers need is turn direction, and this can be readily presented visually or verbally. The importance of left-right turn information was evident in the survey discussed in Chapter 7. From a review of the literature, it was noted no comparisons have been made between auditory only and a combined auditory-symbol display (see Table 8.1). This chapter has investigated the effectiveness of visual, auditory and a combination of the two media. The aim was to identify the most appropriate media for presenting simple turn route guidance information to drivers across ages.

8.3. Method

8.3.1. Participants

Twenty four participants took part in this experiment; 15 of whom were male and 9 female. Participant's age ranged from 18 to 69. They were Loughborough residents who were naive to the research topic. All held full UK driving licences and had normal or corrected to normal vision. They were all paid for their participation. Three of the participants were elderly (> 60 years, 2 males). The original sample had a higher proportion of elderly drivers but, two of the first five were unable to complete the experiment because of feelings of nausea. Only one of the 21 younger participants reported any nausea. Consequently, recruitment of elderly drivers was stopped on ethical grounds. A high rate of driving simulator sickness amongst elderly people (> 50%) has also been reported in the literature (Walker et al., 1991; Ward & Parkes, 1996).

8.3.2. Apparatus

The experiment was conducted on a five screen fixed base driving simulator. It presented forward and side views of approximately 200° with respect to the driver (see Figure 8.1). The visual scene was a computer generated urban environment which contained other vehicles, junctions and buildings. Roads were laid out in a rectangular grid. The simulator provided limited haptic feedback, for example the seat thumped when mounting a kerb. Appropriate driving noise was also provided, for example there were engine noises and the sudden application of the brakes resulted in screeching.

The presentation of route guidance information was experimenter controlled. There were two direction symbols, left and right. They were white opaque arrows illuminated from behind. They subtended a visual angle of 3° and were positioned just outside the steering wheel at the *ten to two* positions, left arrow on left and right arrow on right. All navigation instructions were presented at a fixed distance prior to the manoeuvre. The turn arrows were illuminated until the manoeuvre was completed (or junction missed). A digitised female voice was used to present the auditory information. The instructions were *next left* or *next right.*

The presentation of the combined auditory and visual information was sequential such that visual information was presented immediately after the auditory. This was done because, with simultaneous presentation of these two modalities, auditory information is less likely to be processed because people tend to shut it out in favour of vision (Posner, Nissen, & Klien, 1976). There is also an age related decrease in ability to select and focus on a single information source when there are competing sources (e.g., McDowd & Birren, 1990). Other researchers have recommended this sequential arrangement for presenting combined visual and verbal information (e.g., Alm et al., 1992; Pauzie & Anadon, 1993).

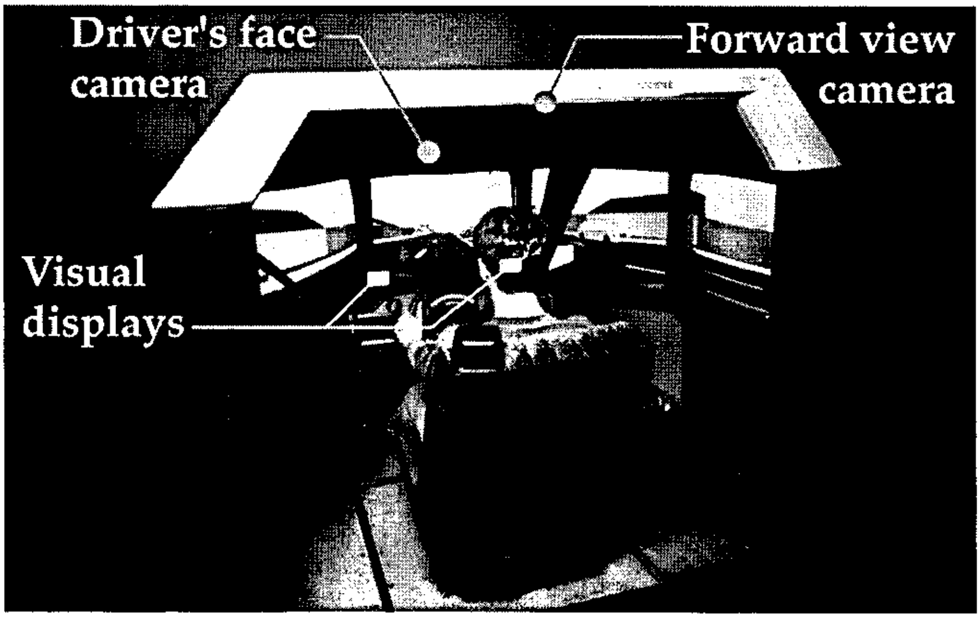


Figure 8.1. Forward view of driving simulator.

Video cameras were used in the experiment to record the participant's face and the forward view. The two images were mixed together in real time and a time signal overlaid.

8.3.3. *Procedure*

Participants were given a car–following task to familiarise themselves with the simulator. Four methods of presenting navigation information were employed: visual, auditory, visual-auditory and car following (the control). There were four different routes approximately five miles in length with an equal number of left and right turns (20 of each). All participants drove the four routes, and the order of presentation was counter-balanced across conditions. Each route took approximately 15 minutes to complete. The experimenters recorded navigational errors (missed or wrong turns) and driving performance during the trials in a notebook. Workload measures were obtained after each condition using a version of the NASA R-TLX (Byers, Bittner, & Hill, 1989) modified for driving (Fairclough, 1991). At the end of the experiment a questionnaire was administered to establish subjective preferences and some background information.

The video recordings of drivers' visual behaviour were transcribed manually onto a spreadsheet according to the method of Lansdown and Fowkes (1995). Location and duration of glances away from the forward view were measured. Glance duration was measured in 0.5 second intervals and location was classified into five regions of the visual scene: right region, left region, driver mirror, instrument panel and route guidance system.

8.4. Results

8.4.1. *Subjective Mental Workload*

Mean subjective mental workload ratings (NASA R-TLX, see Appendix E) for the route guidance conditions are shown in Table 8.2. The sample size prevented a statistical comparison between age groups. Overall imposed mental workload was shown to be significantly different across methods of presenting information ($F(3,23) = 8.65, p < 0.0001, \eta^2 = 0.09$). There were no significant differences between conditions for the *physical demand* ratings. Significant differences were found for the other five ratings. Post-hoc comparisons of means were made using the Tukey test. Letters below the means in Table 8.2 indicate the results of the comparisons. Conditions marked with the same letters are not significantly different. Post-hoc comparisons were only performed on conditions where significant main effects were present. The visual only condition was rated as being more demanding overall than the auditory only and visual-auditory conditions. The same pattern of ratings applied to the *mental demand, mental effort,* and *distraction* sub-scales. The auditory only and visual-auditory conditions were not rated as being significantly different for any of the workload ratings. The control condition (car following) was rated as having significantly more *time pressure* than the visual-auditory condition and more *mental demand* than the auditory only and visual-auditory conditions. Lastly, participants rated the visual only condition as having significantly higher *stress level* than the visual-auditory condition.

Table 8.2. Mean subjective mental workload ratings* (standard deviation).

	Control	Visual	Auditory	Visual-Auditory
Mental demand	52.3 (25.8) B	58.3 (24.6) B	42.9 (22.1) A	40.0 (20.6) A
Mental effort	48.8 (24.4) AB	57.3 (18.9) B	45.1 (19.0) A	42.4 (16.1) A
Physical demand	29.1 (18.0)	33.9 (21.2)	30.9 (19.4)	26.8 (16.7)
Time pressure	41.7 (23.7) B	36.4 (21.8) AB	29.7 (22.4) AB	26.0 (19.5) A
Distraction	32.5 (24.1) A	46.6 (23.2) B	25.9 (16.4) A	31.4 (20.7) A
Stress level	36.3 (20.8) AB	41.5 (22.3) B	33.5 (22.9) AB	30.0 (18.6) A
Mean workload	40.1 (16.9) AB	45.7 (16.6) A	34.7 (16.3) B	32.8 (14.6) B

*Means with the same letter are not significantly different ($\alpha = 0.05$).

The small proportion of elderly participants in the sample prevented a statistical comparison of mental workload across age groups. However, the mean mental workload ratings were in the same order across conditions for both age groups. Thus, the visual only condition had the highest workload rating and the visual-auditory condition had the lowest rating for both young and elderly drivers.

8.4.2. Visual Behaviour

Participants' mean glance duration across regions of the visual scene are presented in Table 8.3. There were significant differences in left region glance duration ($F(3,23) = 1.69$, $p < 0.01, \eta^2 = 0.01$), driver mirror ($F(3,23) = 3.90$, $p < 0.01, \eta^2 = 0.06$) and mean glance duration ($F(3,23) = 3.25$, $p < 0.05, \eta^2 = 0.03$) for the different experimental conditions. Post-hoc comparisons of means were made using the Tukey test for regions with significant differences. Drivers' glances to the left region were significantly shorter in the control condition than either the auditory or visual-auditory conditions. Glances to the rearview mirror were significantly shorter in the control condition than in the visual-auditory condition. Mean glance duration across five regions of the visual scene were significantly shorter for the control condition than for the auditory display condition.

Table 8.3. Mean glance duration (seconds), by region and condition* (standard deviation).

	Control	Visual	Auditory	Visual-Auditory
Right region	0.73 (0.15)	0.77 (0.17)	0.78 (0.19)	0.77 (0.17)
Left region	0.67 (0.11) A	0.72 (0.15) AB	0.74 (0.16) B	0.73 (0.15) B
Instrument panel	0.57 (0.09)	0.58 (0.10)	0.61 (0.22)	0.58 (0.09)
Driver mirror	0.56 (0.08) A	0.58 (0.09) AB	0.60 (0.13) AB	0.64 (0.15) B
Route guidance display	-	0.58 (0.10)	0.61 (0.22)	0.58 (0.09)
Mean glance duration	0.63 (0.08) A	0.66 (0.11) AB	0.68 (0.12) B	0.67 (0.13) AB

*Means with the same letter are not significantly different ($\alpha = 0.05$).

Glance frequencies for the different visual regions and conditions are presented in Table 8.4. There were significant differences in the frequency of glances to the rearview mirror ($F(3,23) = 6.94$, $p < 0.001, \eta^2 = 0.07$) and visual route guidance display ($F(3,23) = 54.80$, $p < 0.0001, \eta^2 = 0.59$) across the different experimental conditions. There was also a significant difference between conditions for mean overall glance frequency ($F(3,23) = 8.99$, $p < 0.0001, \eta^2 = 0.09$). Post-hoc comparisons revealed specific differences in glance frequencies between the types of condition. For the control condition, glance frequency to the rearview mirror was significantly lower than other conditions. Glance frequency to the route guidance display was significantly highest for the visual only display and lowest for the auditory only display. Mean glance frequency across regions of the visual scene was significantly lower for the control condition than in the visual only condition.

Table 8.4. Mean glance frequency per minute, by region and condition* (standard deviation).

	Control	Visual	Auditory	Visual-Auditory
Right region	5.0 (1.7)	4.6 (1.4)	5.2 (1.7)	4.9 (1.4)
Left region	3.7 (1.2)	3.5 (1.0)	3.7 (1.3)	3.6 (1.4)
Instrument panel	0.9 (0.9)	0.7 (0.5)	1.0 (0.9)	0.9 (0.6)
Driver mirror	1.1 (1.1) A	1.8 (1.2) B	1.8 (1.2) B	1.7 (1.0) B
Route guidance display	-	2.5 (1.5) C	0.2 (0.3) A	0.8 (0.5) B
Mean glance frequency	2.1 (0.5) A	2.6 (0.5) B	2.4 (0.6) AB	2.4 (0.5) AB

*Means with the same letter are not significantly different ($\alpha = 0.05$).

Percentages of total time spent glancing to the different regions of visual scene are presented in Table 8.5. There were significant differences across different experimental conditions in percentage of time spent glancing at the rearview mirror ($F(3,23) = 6.81$, $p < 0.001$, $\eta^2 = 0.09$) and visual only route guidance display ($F(3,23) = 48.70$, $p < 0.0001$, $\eta^2 = 0.57$). Percentage of total time spent looking at the forward view also differed significantly across conditions ($F(3,23) = 7.66$, $p < 0.001$, $\eta^2 = 0.08$). Post-hoc comparisons indicated percentage of time glancing to the rearview mirror was significantly less for the control than any other condition. Percentage of time spent glancing to the route guidance display was significantly highest for the visual only display and lowest for the auditory only display. Percentage of total time spent glancing to the forward view was significantly highest for the control condition.

Once again, the small proportion of elderly participants in the sample prevented a statistical comparison of visual behaviour across age groups. A simple comparison of mean percentage time spent glancing to the forward view revealed the same order of differences between elderly and young drivers. Most time was spent glancing to the forward view during the control condition. Total time spent glancing to the forward view was lower for the three elderly drivers than the non-elderly across all conditions. The visual only condition had highest mean glance frequency per minute for both elderly and young drivers. Although significance could not be determined, the means alone indicated that non-elderly drivers had higher mean glance frequencies per minute and shorter mean glance duration across the four experimental conditions.

Table 8.5. Mean percentage time, by region and condition* (standard deviation).

	Control	Visual	Auditory	Visual-Auditory
Right region	6.1 (2.3)	5.9 (1.8)	6.7 (2.5)	6.1 (2.3)
Left region	4.0 (1.5)	4.2 (1.6)	4.5 (1.7)	4.3 (1.7)
Instrument panel	0.8 (1.1)	0.6 (0.6)	0.9 (0.9)	0.9 (0.7)
Driver mirror	1.0 (1.0) A	1.8 (0.9) B	1.7 (1.1) B	1.7 (1.1) B
Route guidance display	-	2.2 (1.5) C	0.1 (0.3) A	0.8 (0.6) B
Forward view	87.9 (3.0) B	85.2 (3.9) A	85.8 (3.9) A	86.2 (3.7) A

*Means with the same letter are not significantly different ($\alpha = 0.05$).

8.4.3. *Subjective Preferences*

Subjective order of preference for the presentation of route guidance information was calculated using paired comparisons. Highest preference for the treatment conditions was: visual-auditory (12), auditory (10) and visual (2). Two of the three elderly drivers preferred the visual-auditory condition and the other preferred the auditory only condition. There were no apparent gender differences among the preferences. Only two participants reported they would not want a route guidance system in their car. Both of these participants were young males.

8.4.4. *Driving and Navigation Performance*

Across all the participants, 30 navigational errors were committed during the experiment; 80% of these occurred with the visual only display condition. These errors mainly constituted missed turns, although some wrong turns were also made. There was no pattern in the occurrence of errors across subjects.

During the experiment sudden braking occurred 85 times, 44% of these were observed in the control condition. There were no noticeable age differences in the distribution of navigational errors or sudden braking.

8.5. Discussion

Subjective mental workload associated with the different display types was highest for the visual only condition. There was no significant difference in mean mental workload with the auditory and visual-auditory displays. Navigation errors were highest for the visual only condition. Subjective preference was highest for the visual-auditory display followed by the auditory only display. Total percentage time and glance frequency were highest in the visual only condition.

Glances to the route guidance systems occurred most frequently during the visual only condition. The addition of auditory information significantly reduced number of glances away from the forward view. This suggests visual demand may be usefully reduced by the use of auditory displays. A reduction was also observed in glance frequencies and percentage time allocated to the guidance system when auditory information was presented. Auditory only information virtually eliminated glances to the route guidance display because there was no information being presented there.

Percentage time glancing to the forward view was highest during the control condition. The vehicle following task would have required participants to concentrate on the forward view to obtain guidance information. This task was not an ideal control condition for wayfinding because it involved some element of pace whereas the other conditions did not. This may have added difficulty not present in other conditions. Participants had to keep up with the target vehicle travelling at a constant speed. They may have preferred to drive at their own pace, although they were instructed to keep their speed around 30 mph (same as target vehicle). In the event that the subject lost the lead vehicle, it would stop to let them catch-up. Interestingly, in comparison with the control, the auditory only condition resulted in similar distraction from the forward view as with conditions where a visual display was present. Thus, participants may have had more opportunity to look away from the forward view in the experimental conditions. Alternatively, they may have needed to look away from the forward view for guidance information.

The mean mental workload ratings and visual behaviour measures (glance frequency and total percentage allocation) suggest that use of the visual only display imposed significantly greater attentional demand on the driver than when accompanied with an auditory component or auditory information alone. Additionally, 80% of all wrong turns occurred in the visual only condition. It must be stated that the relative simplicity and conspicuity of the visual only display could have enabled the participants to detect and respond to the visual stimuli without using foveal vision. Therefore, they may not have needed to glance away from the forward view to attend to the display.

The mental workload, visual demand measures and performance data provide evidence for the superiority of a combined display format over a visual only display. Similar results have been shown previously (e.g., Burnett & Parkes, 1993). This raises issues of whether visual information is essential to a route guidance system or can a speech only system adequately meet users' needs. A speech only system may be favourable compared to a combined system because of the reduced interference with the visual-spatial components of driving. Alm et al. (1992) recommend using verbal information as a primary source of guidance information and visual as a redundant reminder or re-enforcer. The study in this chapter supports their recommendation.

The navigation task in this experiment was a simple one and the benefits of combining auditory with visual displays needs to be further investigated with road trials. The respective benefits of the auditory and visual media may change in a more complex road environment or with the presentation of more complex guidance information. It has been argued that "...it is not possible to base a navigation system on only left-right, and straight ahead messages, if there are complex roundabouts (more than four arms) in the driving environment" (Alm et al., 1992, p. 9). Although left-right instructions are not sufficient to guide drivers through every possible route configuration, they are certainly a necessary part of route guidance. Research in Chapters 6 and 7 indicated that most drivers wanted left-right directions from a passenger.

There were not a sufficient number of elderly participants in this study to draw any statistical conclusions regarding age and display modality. However, differences across treatment conditions for the three elderly participants were comparable to the 21 younger drivers for all the dependent measures (mental workload, visual behaviour, driving performance and preferences). Thus, the same relative conclusions regarding display performance apply to both young and elderly participants.

One noticeable age difference in visual behaviour was that elderly drivers had lower mean glance frequencies per minute and a longer mean glance duration across the four experimental conditions. On average, elderly participants switched glances to the various regions of their visual scene less frequently, and when they did look it was for a longer period of time. This is consistent with research reported in Wierwille (1990). The visual distraction caused by these displays would be greater among elderly drivers than non-elderly drivers. This tendency for elderly drivers to make longer glances away from the road highlights the safety concerns about introducing additional visual information to the driving task. Any distraction from the forward view increases the risk of not detecting a potentially dangerous situation.

Although future studies need to explore these issues with a larger sample of elderly drivers, concerns about using elderly people for research in driving simulators need to be addressed. Research must determine why elderly drivers are susceptible to nausea and how to design less disturbing simulators. The safety and experimental control afforded by simulators make them an essential tool for studying driver behaviour. Although road trials are also a necessary part of research, they do not represent a safe alternative to simulators.

8.6. Chapter Conclusions

The study in this chapter considered different methods of presenting route guidance information for safe and efficient wayfinding. The aim was to identify the most appropriate media for presenting simple turn route guidance information to drivers across ages. It investigated the effectiveness of presenting left-right turn information using visual, auditory (speech) and a combination of the two media. The study was carried out in a simulated driving environment. A combined route guidance system with a simple visual and auditory display was shown to be as demanding as an auditory only system. The visual only display was more demanding than the systems that presented auditory information. These results are based on visual behaviour, subjective mental workload ratings, wayfinding and driving performance, and subjective preferences. For displaying simple route guidance information, it is recommended that verbal displays be used as a primary source of guidance information. Visual displays should only be used as a redundant reminder when the vehicle is in motion. Although, no statistical comparisons across age groups could be made, general trends suggest these results apply to both non-elderly and elderly drivers.

8.6.1. Acknowledgements

This experiment was run with the assistance of Dr. Terry C. Lansdown.[1] The present author is responsible for the planning and analyses of the work described in this chapter. This research was presented at the *13th Triennial Congress of the International Ergonomics Association* (Lansdown & Burns, 1997).

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Chapter 9: Discussion and Conclusions

9.1. Chapter Summary

This chapter provides a summary of the research. The thesis aims are re-examined in relation to the results of the focus group discussions, questionnaire survey and route guidance experiment. A summary of recommendations for how to improve driver navigation performance is offered. Contributions to knowledge and paths for future research are discussed. This last chapter ends with some final conclusions.

9.2. Summary of Research

This thesis examined issues surrounding driver navigation. Emphasis was on the problems of elderly motorists because it is believed they have more problems with navigation than their younger counterparts. This thesis aimed to investigate the prevalence and type of driver wayfinding problems, as well as their causes, consequences and psychological implications. It also sought to determine how drivers plan their routes and find their way in transit. Lastly, this thesis aimed to measure the impact wayfinding problems have on mobility and identify potential solutions to these difficulties.

The comprised three studies. The first study was a preliminary investigation into driver navigation. Focus group discussions were held with elderly and non-elderly drivers. These discussions explored driver wayfinding strategies, problems and new route guidance technology. The second study consisted of a large scale postal questionnaire survey of U.K. motorists. The survey built on what was found in the discussion groups and the literature. It examined respondents' navigation strategies, problems and information needs. The third and final study explored different modes of presenting route guidance information. An experiment was conducted to investigate the safety and efficiency of visual, auditory (speech) and a combined visual-auditory display. Driver performance, visual behaviour, subjective mental workload and preferences were recorded.

9.3. Assessment of Research Aims

The general aims of this project were to research navigation problems among elderly motorists and identify their navigation information needs. It was proposed that an understanding of the problems experienced while navigating would provide insight into what information drivers need to navigate successfully. Furthermore, it was believed that a reduction in navigation problems would serve to enhance driver mobility. The following sections review the thesis results according to the research aims stated in Chapter 1.

9.3.1. Model of Driver Wayfinding

The first aim of the thesis was to propose a model that could describe the process of driver wayfinding and account for errors in wayfinding. This was necessary because no appropriate model describing the process of wayfinding while driving exists. A theoretical model was derived from existing theories and research from the disciplines of human geography, and environmental and cognitive psychology. It combines a popular model of human information processing (Wickens, 1990) with theories of wayfinding and environmental cognition (Chown et al., 1995; Gärling et al., 1984; Passini, 1984). This was described in Chapter 3 and was used as a framework for discussions of the driver wayfinding process throughout the thesis (see Figure 3.2).

According to the model, when drivers encounter a decision point they must resolve the uncertainty of having more than one path option. The information that reduces the uncertainty of wayfinding decisions must be recognised from their perception of the environment or be obtained from a cognitive map stored in memory. Environmental information is used to assess the situation. In situation assessment, drivers consider their progress, orientation and path options. Once they have assessed the environmental information, they must attempt to select the most appropriate path and direction in order to travel to their destination. After the decision is made the driver must execute it at the decision point. This process is repeated whenever drivers encounter uncertainty about their progress along a route. This model effectively described the wayfinding process and could account for the different causes of wayfinding errors.

9.3.2. *Navigation Strategies*

Route Planning

The next aim of this thesis was to find out how drivers navigate. Navigation involves route planning and wayfinding. Wayfinding refers to the decision making process that is required to negotiate a route to a destination. Route planning strategies are the navigational preparations that people make before driving an unfamiliar route. In order to understand driver navigational information needs, the current methods people use to plan their routes and find their way while driving had to be identified. Very little is reported in the literature about this part of driving.

The discussion groups and survey of elderly and non-elderly drivers identified a variety of different strategies for planning and driving on unfamiliar routes. These strategies varied according to the type of trip being taken (e.g., distance and time). Route planning strategies did not differ outside of cities (i.e., motorways, A-roads and B-roads). The most common strategy was to take notes of the route from a map prior to departure. This is consistent with previous research (e.g., Streff & Wallace, 1993). The difference between city planning and other route types was that more drivers would use city maps in cities and road atlas/maps outside cities. The only age differences for the strategies employed were more non-elderly drivers would ask someone for route information and the elderly drivers in the discussion groups emphasised the importance of seeing a route overview before starting. Elderly drivers also reported they were using the same wayfinding strategies they had used throughout their lives.

Wayfinding

Wayfinding strategies are the procedures people use to find their way while driving. They did not differ outside of cities (i.e., motorways, A-roads and B-roads). In the questionnaire survey, the most common strategies for wayfinding on motorways were to rely on memory from route planning and/or refer to maps or notes of the route. These strategies are consistent with the planning strategies described above. The most common wayfinding strategies for driving through an unfamiliar city were: stopping to ask for directions and/or reading a street map. Fewer drivers relied on memory for wayfinding in cities; possibly because the higher frequency of decision points and complexity of road layout make it a less effective strategy. The fact that there are differences between wayfinding within and outside of cities indicates there is a need to distinguish between these environments when examining wayfinding behaviour.

There were age differences in wayfinding strategies. Younger drivers were less likely to stop to ask for directions and elderly drivers less likely to rely on their memory. An age related decline in the ability to recall routes might explain why fewer elderly drivers rely on memory for wayfinding. Their poorer recall of route information makes memory a less reliable source of wayfinding information.

Wayfinding Information Needs

Path information was the most common type of wayfinding information wanted for driving in cities (street name) and on major roads (road number). Otherwise, the information preferred between the environments was different. When driving on major roads people tended to want junction numbers and place names, and for cities they wanted lane position and landmarks. In cities, more women and non-elderly drivers wanted landmark information than did elderly and male drivers.

If a passenger was giving turn information, drivers requested they provide left-right directions, landmarks and road numbers. Proportionally, more elderly drivers preferred road numbers and more younger drivers chose landmarks. This is consistent with the age differences found in preferences for city wayfinding information. With respect to gender differences, more male drivers wanted road number information from a passenger than did female drivers, whereas more females wanted landmark information. A greater female preference for landmark information has been observed in previous wayfinding research (Galea & Kimura, 1993), although not in the context of driving.

9.3.3. *Navigation Problems*

Prevalence of Navigation Problems

Another aim of this thesis was to measure the prevalence of navigation problems amongst the driving population, with particular emphasis being placed on elderly drivers. The most frequent problems reported were *saw a sign too late*, *missed a sign*, and *saw turn too lat*e. The least frequent problems were *misinterpreted directions*, *got lost* and *the route was shorter than expected*. Female drivers reported more frequent problems than males. This is consistent with previous research (e.g., Devlin & Bernstein, 1995). Although it was expected elderly drivers would experience more frequent wayfinding problems, there was no significant age difference. This is attributed to exposure. Since elderly people drive less and avoid unfamiliar routes, they experience less frequent wayfinding problems.

As predicted, drivers rated wayfinding as being more difficult with increasing old age. Female drivers found wayfinding more difficult than males. Similarly, elderly and female drivers tended to rate their wayfinding abilities as being less than non-elderly and male drivers. Although there is no comparable research on wayfinding problems in cars, similar results have been reported about wayfinding on foot (Devlin & Bernstein, 1995).

Types and Causes of Navigation Problems

Another aim of this thesis was to determine the types of navigation problems drivers encounter, as well as their causes, consequences and psychological implications. Some of the factors that affect wayfinding performance became apparent in the focus group discussions described in Chapter 4. The main problems were a lack of wayfinding information and inaccurate information. Elderly drivers tended to report more problems relating to a lack of information. This was mainly considered to be caused by inadequate signage and a lack of confidence. Problems relating to inaccurate wayfinding information did not exhibit any age differences. These problems were caused by inaccurate expectations, and errors in maps, road signs and the advice of others.

A factor analysis of wayfinding problems identified two main distinctions among a set of pre-determined errors. These were decision making errors and errors arising from the faulty detection of route information. The most frequent causes of drivers losing their way reported in the questionnaire survey were: lack of sign, distracted attention, road repairs, obscured signs and inaccurate directions.

These types and causes of wayfinding problems were examined in relation to the theoretical model of navigation (see Figure 7.1). Reason's (1990) theory of human error was applied to the context of wayfinding in an attempt to explain the problems. The three main categories of human error are mistakes, slips and lapses (Norman, 1988; Reason, 1990). Figure 7.1 describes the types of errors and where they are likely to occur in the wayfinding process. In consideration of the results of the questionnaire survey and the wayfinding process, it is believed that on an unfamiliar route, the bulk of wayfinding errors are *mistakes*. Mistakes are incorrect intended responses caused by a misinterpretation or flaw in the choice of responses (Reason, 1990).

Mistakes occur at the situation assessment and decision making stage of wayfinding. They are likely to be caused by inadequate information, and/or constraints on information processing. This interpretation is based on the main factors that emerged in the factor analysis of the wayfinding errors. These causes were also equivalent to Norman and Bobrow's (1975) distinction between *data-limited* and *resource-limited* task performance. The first cause is linked to the navigational degrees of freedom facing the driver. More wayfinding problems would be expected when route choices are complex. Uncertainty is also linked to the quality of spatial information available to the driver, which varies according to its quantity, appropriateness, conspicuity, accuracy and congruity.

The second cause of wayfinding mistakes is constraints on the driver's information processing. Information processing can fail in many ways such as limitations on attention, working memory, logical reasoning and decision making (Wickens, 1992). Wayfinding mistakes would be expected to occur when the driver has insufficient cognitive resources available to make a decision (resource limited). This may happen when the driver is occupied with the priority of maintaining safe control of the vehicle and does not have sufficient spare attention to devote to a secondary task of wayfinding. Distracted attention was one of the most common causes of wayfinding problems reported by drivers in the survey.

Factors that influence wayfinding mistakes can also be considered in relation to the individual or environment. These factors influence both the difficulty of the required decisions and the constraints on information processing. Respondents listed two general environmental causes of getting lost: situation and location. Situational variables can have a negative impact on wayfinding performance by reducing the quality of environmental information (i.e., increasing uncertainty) or placing constraints on the capacity to make wayfinding decisions. Three situational variants that can influence this process were identified in this survey: visibility, traffic conditions and time. The environmental location or context of the wayfinding task also influenced wayfinding performance. Places reported to cause problems were road repairs and diversions, one-way road systems, large complicated junctions and new road layouts.

Individual differences in wayfinding problems also appeared in the survey. Non-elderly drivers were found to blame themselves (e.g., inattention), signs and errors (e.g., missing a turn) more than elderly drivers. Elderly drivers blamed locations (e.g., cities) and situations (e.g., night time) more than younger drivers. It is suggested that these age differences are linked to general driving difficulties because elderly drivers report problems in locations and situations that they prefer to avoid (e.g., heavy traffic). Anything that makes driving difficult for a person would also make wayfinding difficult. Thus, non-elderly drivers may experience fewer wayfinding problems in these particular locations and situations because they find driving less difficult in many situations.

A model depicting the relationship among drivers' individual characteristics and wayfinding problems was proposed in Chapter 3 (See Figure 3.3). This model was altered in Chapter 5 (See Figure 5.1) to account for only those variables which could be measured in a questionnaire. The path analysis conducted in Chapter 6 indicated that the revised model did not describe the data accurately. The lack of fit was attributed to problems with the validity of certain individual difference measures (i.e., health) and missing variables (e.g., personality, navigation strategy, memory, attention and rate of decision making) rather than the structure of the path model itself. Nevertheless, most of the proposed relationships among the variables were significant and they explained a significant proportion of variance in wayfinding problems. Significant partial correlations with wayfinding problems were found for age, vision, spatial ability, and confidence. This suggests that these factors are related to wayfinding performance.

Consequences of Navigation Problems

The emotional consequences of getting lost reported in the survey were predominantly negative. This finding is consistent with Lynch's (1960) description of the seriousness of getting lost quoted at the beginning of this thesis. The survey found the most common feelings people have when lost while driving, irrespective of age or gender, were irritation and frustration. Elderly drivers reported feeling more embarrassed and foolish than younger drivers and more younger drivers reported feeling frustrated and irritated. Females report feeling anxious when lost and more males report feeling embarrassed. Discussion groups identified similar consequences of wayfinding problems.

9.3.4. *Navigation Problems and Mobility*

This thesis also sought to assess the impact navigation problems have on the mobility of elderly drivers. It was believed that wayfinding difficulties decrease the functionality of driving and threaten peoples' mobility. Mobility is the ability to travel independently and conveniently. It is important because it contributes to people's well being by enabling them to independently fulfil their needs (Carp, 1988). Evidence for a link between wayfinding problems and reduced mobility appeared in the focus group discussions. Elderly drivers reported that difficulties with wayfinding would deter them from undertaking a trip to an unfamiliar place.

The survey also explored this relationship between wayfinding problems and mobility. Again, results indicate wayfinding problems do indeed have a negative impact on mobility. This occurs even when accounting for the main predictors of mobility (age, gender, employment, health, fitness, and costs of driving). Similar results occurred for three different measures of mobility (weekly mileage, weekly number of trips, and average driving frequency for non-work activities).

9.4. Recommendations

This thesis has shown that difficulties in navigating are a considerable problem for drivers. They were shown to be related to reduced mobility and tended to evoke irritation and frustration in drivers. Other research has suggested navigation problems contribute to wasted time, wasted fuel and traffic congestion (Jeffrey, 1981). There are a number of possible solutions to these problems among elderly and non-elderly drivers. However, the low feasibility of many of these solutions limit their appeal. For example, an obvious solution would be to have people use more public transportation. This would eliminate their need to drive and any worries about navigation problems. Unfortunately, no current public transportation system can provide the same mobility and freedom as the private car and it is doubtful that one ever will (Rosenbloom, 1993). Consequently, in the foreseeable future, it should be assumed that people will continue to use private automobiles, perhaps even more frequently. Therefore solutions, given this assumption, will have to be directed at assisting navigation in cars.

This section summarises the solutions to navigation problems that were discussed earlier in this thesis. In consideration of the model of driver wayfinding errors, there are a range of potential solutions (see Figure 7.1). If mistakes are the product of high uncertainty and constraints on driver information processing, then solutions will have to reduce this uncertainty and minimise the constraints. These solutions will be discussed in relation to their location; inside the vehicle or outside the vehicle.

9.4.1. *Inside the Vehicle*

In-car navigation support for drivers can come from maps, passengers and new technology. It can also come from the individual driver. Drivers could be trained to improve their navigation strategies and compensate for any individual limitations. Elderly drivers, who tended to report more wayfinding difficulties, might be trained to modify their planning and wayfinding strategies to compensate for specific age-related declines in their ability. Training could make them more aware of their limitations with respect to wayfinding. Making more thorough route plans and travelling with a passenger as a navigator are two ways that could reduce some of their difficulties. Travelling at off peak times and during daylight hours might also improve performance. Anything that makes the driving task less demanding would enable drivers to pay more attention to wayfinding. Perhaps elderly drivers need different types of environmental cues to other drivers. They could be retrained to attend to more salient features of their environment which are more perceptually accessible (i.e., more visible to the ageing eye).

People could be educated about navigation in driver training courses or refresher courses targeted at elderly drivers (e.g., *55 Alive* and *RoadFit*). Drivers might also get information from pamphlets highlighting methods for improving navigation performance. These documents might include details about where people experience problems and methods to overcome these problems. Perhaps training drivers in map reading skills would also help their navigation performance because some have more trouble with maps than others (i.e., elderly and female drivers). Training may even be targeted at building drivers' confidence in their navigational ability.

It is doubtful that these options would appeal to motorists because they impose restrictions on mobility and demand more preparation time and effort. More preparation work would make driving less feasible. However, this may currently be the best option because the existing route guidance infrastructure (i.e., road signs and road configuration) are unlikely to change. Furthermore, it will be some time before route guidance systems become standard equipment in cars.

Most drivers consulted a road atlas to plan their routes. Improving the design of road maps might assist route planning and wayfinding. This approach could be a fast and relatively inexpensive solution to navigation problems. Bell (1997) has suggested that route knowledge acquisition could be improved with segmented strip maps. Computerised maps (e.g., AutoRoute) might be another effective method of simplifying route planning.

New route guidance systems may also offer in-vehicle solutions to wayfinding problems. This technology was specifically designed to assist wayfinding and could aid the process at different levels. They could help reduce uncertainty by displaying additional information to the driver or by supplementing environmental information. Information (e.g., in-vehicle sign displays; Marshall & Mahach, 1996) could be made more accessible by displaying it sooner before decision points and for a longer period of time. This would give drivers more time to assess the information and the ability to read it at their convenience. Another benefit is that the systems can display information using sound instead of vision. This could potentially reduce the demands on drivers' visual resources because they would have less need to search visually for the necessary environmental information.

With respect to the decision making stage of wayfinding, route guidance systems make many decisions for the driver. The system would give the driver the direction and location of each manoeuvre. The driver would then match the instructions or decisions to a location in their forward view and execute the manoeuvres. Route guidance systems could also help direct drivers along routes that are easier to negotiate. They could select routes that have fewer and less complex decision points. And, if the systems were linked to a traffic control network, they could re-direct drivers to avoid heavy traffic conditions. These features might be particularly beneficial to elderly drivers who prefer to avoid these driving situations.

Based on the research assessment of the various forms of displaying in-vehicle route guidance information, a number of conclusions can be drawn (see Chapter 8). The first is that electronic maps should not be used. They have not demonstrated any superiority in performance or safety advantages over conventional road maps (Wierwille et al., 1988).

The electronic maps were also inferior, in terms of performance and safety, to displays using a combination of direction symbols and verbal instructions (Fairclough et al., 1993). Furthermore, the problems with electronic maps are only exacerbated when considering some of the limitations of elderly drivers. Their passive display format, visual complexity and spatial arrangement requires more attention to extract the information necessary to make navigation decisions.

Nevertheless, despite their inadequacy as an in–transit display of route guidance information, electronic maps have potential use for presenting pre-trip planning information. They can assist in the selection of routes and provide a good overview of routes. This is probably the reason why electronic map based in-vehicle route guidance systems are still being promoted. Attempts to develop an information display that will successfully address all drivers' navigational information needs across situations would be difficult. Designers need to examine the different aspects of the navigation task. Different displays should be used to match the different situations and information needs of the user. Pre-transit displays or displays while the vehicle is stopped can have the full attention of the drivers whereas in-transit displays must require minimal amounts of attention.

Consensus in the focus group discussions was for a route guidance system that gave only verbal instructions when the car was moving. Participants believed instrument panel or head-up displays would be distracting and too difficult to use while in transit. However, from experience they liked to have maps to provide a visual overview of the route when necessary. Similar concerns were documented in research by Streeter et al. (1985). The study described in Chapter 8 found a combined route guidance system with a simple visual and auditory display was shown to impose as much demand as an auditory only system. From this, it was recommended that verbal displays be used as a primary source of guidance information and visual displays as a redundant reminder. From the survey, the guidance information drivers wanted was road number, place name, and junction information when travelling outside cities. In cities, they wanted street names, lane position and landmarks.

The safety of these systems will have to be thoroughly assessed before they are installed. For example, there is an interesting concern relating to the motivation or need to search for route guidance signs. A route guidance system has the potential to provide drivers with most of the information necessary for effective wayfinding. Consequently, drivers may not need to search the environment for guidance information. A decreased need to search for guidance signs while using a route guidance system may cause drivers to miss important safety critical signs (i.e., advisory or mandatory warning signs). This would have dangerous implications for road safety.

9.4.2. Outside the Vehicle

There are three general changes to the road environment that might assist driver wayfinding: reducing the complexity of the road geometry, making the road network more consistent, and improving signage. The first two solutions would be difficult to achieve. The complexity of the existing road network could not be reduced easily. Future roads could be designed with consideration to assisting route navigation. One approach might be to make the road configuration more predictable (e.g., a grid system). The introduction of distinct features or landmarks in the road environment might also help drivers to find their way. Inconsistencies or anomalous situations within the road system are another cause wayfinding problems for drivers. These problems occur because information in the environment contradicts driver expectations (i.e., their cognitive schema; see Chapter 3). Encouraging greater standardisation in the road system should reduce some of the difficulties caused by inaccurate driver expectations. For example, roundabouts could be made to the same specifications throughout the road system.

The most promising solution to driver navigation problems will be directed at improving road signs to support accurate situation assessment and decision making. Road signs are an important source of route guidance information. Route guidance signs (e.g., place names, road numbers, street names, distance signs, direction signs, lane information and road layout signs) provide drivers with information required to make wayfinding decisions. They were blamed most frequently for wayfinding difficulties. This research identified that current signage in the U.K. could be improved significantly. Similar conclusions have been recently made by other British researchers (Glover, 1996).

Common problems with signs were: lack of signs, obscured signs, badly placed signs, insufficient information on signs, damaged signs and confusing signs. They need to be more conspicuous, easier to understand and legible from further away. Other improvements are to have more continuity along a route and ensure that signs are better maintained. Lastly, elderly drivers wanted road signs to be placed after intersections to confirm their last manoeuvre (e.g., road number). This would help reduce some of the uncertainty caused by a lack of confidence.

9.5. Contributions to Knowledge

This thesis examined issues surrounding driver navigation. Emphasis was on the problems elderly motorists have with navigation. A review of the literature on elderly drivers and driving navigation provided an impression of what was known about these broad research topics (see Chapters 2 & 3). A substantial body of research existed on the relationship between ageing and human performance (e.g., Birren & Schaie, 1990). Less was known about the ageing driver (NRC, 1988; Rothe et al., 1990) and very little was known about driver navigation (Mark & McGranaghan, 1988; Schraagen, 1990). Theories of general wayfinding had to be adapted to the context of driving from the disciplines of human geography, and environmental and cognitive psychology. Yet, even within these disciplines, there is a lack of knowledge about what information people generally need to find their way (Gluck, 1991; Mark & Frank, 1991). Furthermore, no research had specifically focused on ageing drivers and navigation prior to this thesis.

It is believed this thesis contributes to knowledge within the fields of ageing and environmental psychology. However, its most meaningful contribution is to the discipline of transport psychology/human factors. The remainder of this section describes some of these contributions.

The contributions to knowledge this thesis makes mirror the research aims. A theoretical model was developed to described the process of wayfinding while driving. This new model effectively described the wayfinding process and accounted for different causes of wayfinding errors. The route planning and wayfinding strategies of drivers were identified. No prior research had examined these strategies across different situations and individuals. This thesis also identified driver information needs for wayfinding.

Another contribution to knowledge was the identification of population differences in the prevalence of navigation problems. This thesis documented the types of navigation problems drivers have and their causes. Some of the emotional consequences of these problems were also discovered. It has helped to understand more about how to display route guidance information to drivers across ages. It identified some of the individual causes of driver wayfinding problems and provided recommendations for how to reduce them. The research provided further information about the driving activities of elderly drivers in relation to non-elderly drivers. This thesis also demonstrated that wayfinding problems have a negative impact on driver mobility.

Lastly, this thesis contributed to the research on in-vehicle route guidance systems. It examined a neglected issue within the research literature by making comparisons between the performance of an auditory only and a combined auditory and visual route guidance display.

9.6. Directions for Future research

The results and discussions presented in this thesis have raised many additional research questions. This section describes some of the avenues for future research. This proposed research should consider the needs of all drivers, especially the elderly.

This research relied on self-report data of driver navigation behaviour. The advantage of this approach was that it could provide a broad impression of how drivers behave. However, in order to identify driver navigational requirements, research is needed to gain a more detailed account of navigation behaviour. One approach would be to have a sample of drivers maintain a diary describing all of their unfamiliar trips. They could also submit their route notes for examination. This would provide a detailed record of their planning and wayfinding strategies and problems. This might also enable a quantification of wayfinding problems which would help to determine the amount of time wasted by them. The evidence could be used to convince transport policy makers about the magnitude and costs of wayfinding problems.

The next step would be to run a field trial with drivers along a variety of unfamiliar routes with different road types (e.g., city and rural) and traffic conditions. Subjects would be told to request information whenever they are faced with uncertainty. The timing and content of information needs could be identified through an analysis of their verbal protocols and video recordings of the roadway.

This thesis asked drivers to state their preferences for navigational information. These preferences may not be the best information in terms of safety and effectiveness. This is because the participants in this research may not have known what they really need. Research should try to determine the safest and most effective navigational information. The study proposed in the previous paragraph could also investigate this research question. Comparisons of wayfinding performance could be made between individuals requesting different types of information. This would determine which information leads to the best performance.

It might also be informative to investigate the visual behaviour of drivers with different experience of the same route (unfamiliar and familiar). Comparisons between the groups of drivers would provide an idea of how visually demanding wayfinding is for drivers on unfamiliar routes. A number of questions could be answered by this research. Do drivers on unfamiliar routes display a significant or unsafe increase in visual distraction from the road ahead? Where do drivers look for wayfinding information on unfamiliar routes?

Future research must determine why elderly drivers are more inclined to become nauseous while driving in a simulated environment. The safety and experimental control afforded by simulators make them an essential tool for studying driver behaviour. Although road trials are also a necessary part of research, they do not represent a safe alternative to simulators. There is a need for less nauseating simulators.

The research reported in this thesis only considered the objective component of mobility (i.e., actual distance and frequency of travel). The qualities of mobility in terms of independence and convenience were not assessed. Neither was subjects' perceived ability to travel independently and conveniently. Does the avoidance of unfamiliar trips reduce drivers' ability to fulfil their needs? Although it is clear from the survey that wayfinding problems reduce mobility in terms of the amount of driving, it is uncertain whether they infringe on the quality of this mobility. For example, wayfinding problems could restrict drivers' experiences of new places and their associated activities. The relationship between wayfinding problems and these subjective aspects of mobility need to be investigated. This could be included as part of the diary study described above or focus group discussions could be held to specifically address this topic.

This thesis explored a model of individual variables contributing to wayfinding performance. Although this model could significantly predict wayfinding performance, a path analysis revealed that it did not fit the data. This lack of fit was attributed to limitations in the construct validity of certain variables and missing paths. Future research should attempt to explore the relationship between individual characteristics and wayfinding performance with an emphasis on the construct validity of the measures. A laboratory experiment would provide a better opportunity to measure those variables that could not be measured by questionnaire (i.e., personality, navigation strategy, memory, attention and rate of decision making). This might provide a better understanding of the relationship among age, and other individual characteristics, to wayfinding performance.

There are many research paths for exploring how to improve driver wayfinding performance. These can be focused at the driver, road environment and vehicle. The most effective approach to reducing wayfinding problems will likely involve a range of these strategies. The first approach is directed at the driver. An effort should be made to research effective methods for training drivers to improve their navigation skills. Research should also try to determine whether training can improve navigation performance. Although additional training demands more effort from drivers, it could be a good first step because other solutions may not be possible for some time.

There are various ways of assisting wayfinding in the road environment. Research should explore some of these methods. One approach might be to install road markings that provide drivers with a better sense of natural continuation along a route. Local streets might be distinguished by a different appearance from through roads (e.g., painted surface markings, pavements). The effectiveness of different markings could be explored with drivers in a simulated road environment so as to avoid the time and costs of implementation.

Improvements to guidance signs are the most promising environmental solution to assisting navigation. A series of recommendations for how to improve signs were offered earlier in this chapter. Further research is needed to determine whether these would indeed have a positive impact on wayfinding. The optimal configuration of guidance signs needs to be identified. Little is known about the ideal positioning and information content of guidance signs. Methods for enhancing sign conspicuity, legibility and comprehension distance need to be developed and assessed. Much of this research could be conducted in simulated road environments; as long as they could represent the guidance signs and driving task with a reasonable amount of fidelity.

Certain groups of drivers experience above average difficulties reading maps (i.e., elderly and female drivers). This would suggest that there is room for improvement in the design of conventional road maps. More research is needed to identify ways in which road maps, both conventional and computer based, can be improved to assist driver wayfinding. Various research questions need to be addressed: What features of road maps make them better for route planning? What helps drivers to identify their current location and destination on a map? How can maps be improved to help drivers identify and select path options? Are there ways to design maps to enhance the recall of routes when wayfinding?

There are many research questions about route guidance systems that need to be addressed before they can be considered safe and effective for all potential users. Following-up from the route guidance display modality experiment in Chapter 8, an effort should be made to research the effectiveness of more complex visual-auditory display combinations using the information preferences identified in the survey. For example, there is a need to determine how to effectively display landmark or lane information. Although left-right instructions are certainly a necessary part of route guidance, they are not sufficient to guide drivers through every possible route configuration. Future research should also examine all the possible road configurations and identify what types of guidance information is required to safely negotiate them.

The experiment in this thesis presented the auditory route guidance instructions binaurally. An effort should be made to investigate if spatial coding of auditory left-right instructions improves driver response to guidance information. One advantage of visual displays over auditory displays is they can readily present spatial information. Auditory displays are not compatible with this type of information (Wickens, 1990). Presenting left turn instructions to the drivers' left ear, and vice versa, may avoid the confusion some people have in interpreting left-right directions.

9.7. Thesis Conclusions

From the research conducted in this thesis it can be concluded that navigation performance tends to decline in old age. This has a negative impact on driving mobility. Solutions to navigation problems are needed because safe and efficient navigation is essential to independent and convenient travel. Navigation problems are caused by uncertainty and restrictions to information processing. The most promising solution to these problems would be to enhance the quality of guidance information through improved road signage. In-vehicle route guidance systems might also help drivers with navigation if they are designed to meet their varied information needs.

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Appendix A

Discussion Schedule

Introduction

Thank participants.

The purpose of this discussion to identify peoples' navigation strategies and the problems they have in trying to find their way by car. Also, I hope to discuss some possible solutions to these problems.

The discussion is being recorded so that I can transcribe it later. All of your comments will remain anonymous. I'll stop things in 90 minutes and we'll have a break half way through. Do you have any questions?

Discussion Points

- Self-introductions.

  Name
  How did you find your way here?
  How long have you been driving?

- Describe your last trip or a memorable trip to an unfamiliar place.

  Where and how far?
  Did you make any plans before it?
  How did you find your way while driving? (alone?)
  Did you have any problems?
  Would you have done it differently?

- Discuss the methods drivers use to find their way by car.

  Distinguish between planning and executing.
  Do you change your methods depending on where you are going or how familiar you are with the location?
  Do strategies change according to where you're driving? – motorways, major roads, minor roads and in cities?
  Have your strategies changed in recent years?

- What are the biggest problems drivers have in trying to find their way while driving?

- Think about the last time that you got lost.

  Where was it?
  Why did you get lost?
  What do you do when you get lost?

- What are the implications of navigation problems?

- What would be the best navigational assistance that you could have?

- New technology

  What have you heard about route guidance systems?
  What do you think about new technological aids to navigation?
  What information would you want to be given to help you find your way?

Conclusion

Is there anything else about navigation that you would like to share that we have not yet touched upon?

Describe where am I going with this research.

Thank participants.

Appendix B

Response Rate Analysis

There has been some interest in how certain features of survey design influence response rates (e.g., Jobber, 1993). A tangential enquiry was conducted as part of this survey to determine whether response rates were influenced by an affiliation to either a business or academic institution. It was believed that people might respond more favourably to a survey motivated by research rather than business interests. Responding to a university may be construed as being a more charitable act than responding to a profit oriented business.

In order to explore the relationship between association and response rates, half of the questionnaires sent out had Automobile Association (AA) branded covering letters and half had Loughborough University branded covering letters (See Appendix D). A pen was enclosed as an incentive with all letters. A reminder with the same affiliation was mailed to non-respondents three weeks after the initial send-out.

The total number of respondents was 1184. There were 1950 questionnaires sent out initially. Seventy of these were considered invalid because the addressee had moved, died or stopped driving. Thus the response rate was calculated from a total 1880 potential respondents. This gave a response rate of 63%.

There were 563 AA branded questionnaires returned and 621 university branded questionnaires returned. A binomial sign test was conducted to determine if there was a significant difference between these response rates; the 2-Tailed $p = 0.097$. Also, there was no difference in the pattern of responses to branding by age (old and young).

So industrial or academic branding does not have much of an effect on response rates. Unfortunately, this result is not entirely conclusive because there were some potential confounds. For example, there was no mention of the AA in the letters that were university branded and the university was mentioned in the AA branded letters. Practicalities required a university return address and an explanation for the collaboration between the AA and the university. Consequently, there may have been a significant difference in response rates if there had been no mention of the university in the survey with the industrial affiliations.

Appendix C

Driving Questionnaire

Driving Questionnaire

This questionnaire is divided into sections dealing with different aspects of your driving. Please read each item carefully. Some questions provide a line for you to print your answer ....*answer*.. or they ask you to tick a box ☑ . Only tick one box unless you are asked to do otherwise. If you decide to change your response, please put a cross through it (e.g., ☒) and tick your new response. Even if you are not sure about the answer, do not leave the item blank, pick the answer that is closest to what you think. It is important that you complete all the sections and answer every question.

Driving Experience

1. How often is there a car available for you to drive?
   - ❑ always
   - ❑ most days
   - ❑ more than once a week
   - ❑ once a week
   - ❑ less often than once a week
   - ❑ never

2. If you could change the amount of driving you do now, would you:
   - ❑ drive more often
   - ❑ drive about the same amount
   - ❑ drive less often
   - ❑ never drive

3. How old were you when you first got your driver's licence? .... years old.

4. Approximately, how many miles do you drive in an <u>average</u> week?
   - ❑ less than 10 miles
   - ❑ between 10 and 39 miles
   - ❑ between 40 and 99 miles
   - ❑ between 100 and 199 miles
   - ❑ between 200 and 300 miles
   - ❑ more than 300 miles

5. For how many years have you driven regularly?
   (driving more than once a week) .... years.

6. How does the cost of running your car influence the amount (time and distance) of driving you do? (e.g., the price of petrol, insurance and maintenance)
   - ❑ Increases amount of driving a lot
   - ❑ Increases amount of driving slightly
   - ❑ No impact on amount of driving
   - ❑ Decreases amount of driving slightly
   - ❑ Decreases amount of driving a lot

7. Has anything in the last 5 years caused you to reduce the amount you drive (e.g., health)?
   ❑ Yes ❑ No

If yes, please describe ....

....

....

8. How often do you drive alone?

❑ Always ❑ Often ❑ Sometimes ❑ Rarely ❑ Never

9. How important to you is being able to drive?

❑ Extremely important ❑ Very important ❑ Slightly important ❑ Not very important ❑ Not at all important

10. What are the 3 most important activities that you need your car for? (e.g., for business)

1. .... 2. ....

3 ....

11. In the last 7 days, please estimate the number of **familiar** trips that you drove on.

__Familiar__ refers to a place that you have been to before and know how to find. You would not need any help from a road map/atlas or road signs to find a __Familiar__ place.

The approximate number of familiar trips that you drove last week was:.....................

12. In the last 7 days, please estimate the number of **unfamiliar** trips that you drove on.

__Unfamiliar__ refers to a place that you need help to find. __Unfamiliar__ also includes routes that you do not know. For example, you could take an unfamiliar route to a place that you have been to before.

The approximate number of unfamiliar trips that you drove last week was :...............

13. Was the amount of driving you did in the last 7 days:

❑ more than usual ❑ about average ❑ less than usual

14. How often do you drive to an unfamiliar place **within** 30 miles of where you live?

❑ every day ❑ once a month
❑ more than once a week ❑ once every 2 to 6 months
❑ once a week ❑ once a year or less
❑ more than once a month ❑ never

15. How often do you drive to an unfamiliar place **farther** than 30 miles from where you live?

❑ every day ❑ once a month
❑ more than once a week ❑ once every 2 to 6 months
❑ once a week ❑ once a year or less
❑ more than once a month ❑ never

16. Would you say that your driving habits have changed within the last 5 years?

❑ Yes ❑ No

If yes, how?..

....

....

17. **Please indicate how often you drive for each activity below.**

	Most days	More than once a week	Once a week	More than once a month	Once every 2 to 6 months	Once a year or less	Never
Shopping	❑	❑	❑	❑	❑	❑	❑
Social visits	❑	❑	❑	❑	❑	❑	❑
Holidays (includes weekend travel)	❑	❑	❑	❑	❑	❑	❑
Work (includes volunteer work)	❑	❑	❑	❑	❑	❑	❑
Errands (e.g. banking, post office)	❑	❑	❑	❑	❑	❑	❑
Recreation (e.g. cinema)	❑	❑	❑	❑	❑	❑	❑

18. **For each of the following driving conditions, please indicate to what extent you try to avoid them.**

	Try to avoid completely	Try to avoid if possible	Do not avoid
Bad weather (e.g., snow, fog)	❑	❑	❑
Night-time	❑	❑	❑
Dawn or dusk	❑	❑	❑
Rush hour traffic	❑	❑	❑
Driving alone	❑	❑	❑
Motorways	❑	❑	❑
Dual carriageways	❑	❑	❑
Country lanes	❑	❑	❑
Roundabouts	❑	❑	❑
Right turns	❑	❑	❑
Town centres	❑	❑	❑
Large junctions	❑	❑	❑
One-way systems	❑	❑	❑
Road works	❑	❑	❑
Unfamiliar places	❑	❑	❑
Unfamiliar routes	❑	❑	❑

19. How do you get about locally most often? *Please tick one box only*

❑ drive yourself ❑ get a lift from an acquaintance
❑ bicycle ❑ walk
❑ bus/coach ❑ other ....(please state).

20. How do you travel long distances most often (more than 30 miles)?
Please tick one box only

❑ drive yourself ❑ get a lift from an acquaintance
❑ train ❑ bus/coach
❑ other (please state).

The following section asks you questions about how you plan your routes. **Planning** refers to the preparations you make before driving to an unfamiliar place. For example, planning may involve looking at a map or asking a friend for directions. This planning could occur before you get in your car or at some point along the route.

21. Below is a list of strategies **(A-H)** that some people use to **plan their routes**. Please indicate which strategy, if any, you would use in each situation (questions 1-4). You may use one of the following strategies, more than one, or none at all.

    A consulted a road atlas/map
    B looked at city map
    C had an acquaintance plan the route
    D went without planning
    E made notes of the route
    F made a sketch map of the route
    G contacted a motoring organisation
    H asked someone for the route information

    *Fill in one or more letters corresponding to the A-H options above and/or give an **other** strategy that you use in this situation (e.g.,* Strategies .............*E.H*.....*).*

    1. How did you plan your last trip that included an unfamiliar motorway?
       Strategies ....
       Other ....(please state).
    2. How did you plan your last trip that included an unfamiliar major road (e.g., A-road)?
       Strategies ....
       Other ....
    3. How did you plan your last trip that included an unfamiliar minor road (e.g., B-road)?
       Strategies ....
       Other ....
    4. How did you plan your last drive through an unfamiliar city?
       Strategies ....
       Other ....

22. **For each of the following activities, please indicate whether you find them easy or difficult.**

	Very difficult	Difficult	Neither easy nor difficult	Easy	Very easy	Do not Know
Using a road atlas/map to plan a route	❑	❑	❑	❑	❑	❑
Asking someone for route information	❑	❑	❑	❑	❑	❑
Using a motoring organisation to plan a route	❑	❑	❑	❑	❑	❑
Making a sketch to plan a route	❑	❑	❑	❑	❑	❑
Making notes to plan a route	❑	❑	❑	❑	❑	❑

23. Is there anything you could do to improve the way you plan your routes

❑ Yes ❑ No

If yes, please describe ....

....

....

Finding Your Way While Driving

The following section asks questions about how you find your way while driving. In this section we are interested in the step by step process of wayfinding. This includes such things as how you know where to turn and in which direction to go. **While Driving** means when you are en-route to your destination (e.g., while the car is in motion or when you stop at a lay-by).

24. Do you keep a road atlas/map in your car? ❑ Yes ❑ No

25. Do you keep a local street map in your car? ❑ Yes ❑ No

26. How do you prefer to travel in a car?

❑ driving yourself
❑ as a passenger
❑ no preference

Why? ....

27. How often do you stop to read a map or route notes when trying to find your way?

❑ Always ❑ Often ❑ Sometimes ❑ Rarely ❑ Never

28. How often do you read a map or route notes when trying to find your way (while the car is moving)?

❑ Always ❑ Often ❑ Sometimes ❑ Rarely ❑ Never

29. How satisfied are you with your method of finding your way while driving?

❑ Very satisfied ❑ Satisfied ❑ Neither satisfied nor dissatisfied ❑ Dissatisfied ❑ Very dissatisfied

30. How would you describe your sense of direction?

❑ Very good ❑ Good ❑ Average ❑ Poor ❑ Very Poor

31. **For each of the following driving tasks, please indicate your ability.**

	Very Good	Good	Average	Poor	Very Poor
Finding your way to an unfamiliar place	❑	❑	❑	❑	❑
Reading maps	❑	❑	❑	❑	❑
Distinguishing between right and left hand directions	❑	❑	❑	❑	❑
Telling which direction is north	❑	❑	❑	❑	❑
Seeing what road signs say	❑	❑	❑	❑	❑
Reading road signs while your car is moving	❑	❑	❑	❑	❑

32. Below is a list of strategies (A-G) that some people use to **find their way while driving.** Please indicate which strategy, if any, you would use in each situation (questions 1-4). You may use one of the following strategies, more than one, or none at all.

A rely on your memory from studying the route earlier
B read a sketch of the route
C read a road atlas/map
D read a street map
E read route notes
F stop and ask someone for directions
G try and find your way without help from the other methods above (i.e., by trial and error)

Fill in one or more letters corresponding to the A-G options above and/or give an ***other*** *strategy that you use in this situation (e.g.,* Strategies.............*B F*.....*).*

1. If you were travelling alone to an unfamiliar city, how would you find your way along an **unfamiliar motorway** while driving there?
   Strategies ....
   Other ....(please state).

2. If you were travelling alone to an unfamiliar city, how would you find your way along an **unfamiliar major road** while driving there?
   Strategies ....
   Other ....

3. If you were travelling alone to an unfamiliar city, how would you find your way along an **unfamiliar minor road** while driving there?
   Strategies ....
   Other ....

4. If you were travelling alone to an unfamiliar city, how would you find your way to a **specific destination within the city** while driving there?
   Strategies ....
   Other ....

33. **For each of the following activities, please indicate how easy or difficult you find them.**

	Very difficult	**Difficult**	**Neither easy nor difficult**	**Easy**	**Very easy**
Finding your way on an unfamiliar motorway	❑	❑	❑	❑	❑
Finding your way on an unfamiliar major road	❑	❑	❑	❑	❑
Finding your way on an unfamiliar minor road	❑	❑	❑	❑	❑
Finding your way through an unfamiliar city	❑	❑	❑	❑	❑
Finding an unfamiliar location (e.g., a house)	❑	❑	❑	❑	❑

34. Are there any changes that you would make to improve road signs?

❑ Yes ❑ No

If yes, please describe ....

....

....

....

35. **For each of the following situations, please indicate how frequently you have experienced them while trying to find your way.**

	Always	Often	Sometimes	Rarely	Never
Missed a road sign	❑	❑	❑	❑	❑
Saw a road sign too late to respond	❑	❑	❑	❑	❑
Saw a turn too late to respond	❑	❑	❑	❑	❑
Turned in the wrong direction	❑	❑	❑	❑	❑
Turned before you were supposed to	❑	❑	❑	❑	❑
Chose the wrong lane	❑	❑	❑	❑	❑
Drove past your destination	❑	❑	❑	❑	❑
Went off your planned route	❑	❑	❑	❑	❑
Found an unexpected turn on the route	❑	❑	❑	❑	❑
Passed the correct exit off a roundabout	❑	❑	❑	❑	❑
The route was longer than you expected	❑	❑	❑	❑	❑
The route was shorter than you expected	❑	❑	❑	❑	❑
Had doubts about being on the correct route	❑	❑	❑	❑	❑
Misinterpreted your directions	❑	❑	❑	❑	❑
Had inaccurate directions	❑	❑	❑	❑	❑
Got lost	❑	❑	❑	❑	❑

36. How do you feel when you get lost while driving? *You may tick more than one box.*

❑ Irritated ❑ Embarrassed ❑ Foolish
❑ Wise ❑ Calm ❑ Safe
❑ Afraid ❑ Anxious ❑ Confident
❑ Relaxed ❑ Happy ❑ Doubtful
❑ Frustrated ❑ Comfortable
❑ Other ....(please state)

37. What 3 types of route information would you find most useful on a a trip along a **motorway or dual carriageway?** *You may tick 3 boxes.*

❑ landmarks (e.g., a pub) ❑ place names (e.g., Loughborough)
❑ road numbers (e.g., M25) ❑ left-right directions (e.g., turn left)
❑ road layout (e.g., roundabout) ❑ distances (e.g., 3 miles to ...)
❑ compass directions (e.g., north) ❑ junction numbers (e.g., junction 23)
❑ others ....(please state)

38. What 3 types of route information would you find most useful on a trip through a **city or town?** *You may tick 3 boxes.*

- ❑ landmarks (e.g., a pub)
- ❑ road numbers (e.g., M25)
- ❑ street names (e.g., High St.)
- ❑ distances (e.g., 3 miles to ...)
- ❑ lane position (e.g., left lane)
- ❑ left-right directions (e.g., turn left)
- ❑ road layout (e.g., roundabout)
- ❑ compass directions (e.g., north)
- ❑ others ....

.... (please state)

39. If a passenger was giving you directions while you were driving, how would you want them to identify the location of a turn? *You may tick more than one box.*

- ❑ landmark
- ❑ far distance (e.g., 2 miles)
- ❑ near distance (e.g. 200 yds)
- ❑ street name
- ❑ a road number to follow
- ❑ left-right directions
- ❑ number of streets (e.g. 3 streets)
- ❑ pointing where to turn
- ❑ others ....

....(please state)

40. **For each of the following statements, please indicate how often you experience them.**

	Always	Often	Sometimes	Rarely	Never
I slow down to read unfamiliar road signs	❑	❑	❑	❑	❑
I have trouble finding where I parked my car	❑	❑	❑	❑	❑
I need prescription glasses or contact lenses for driving	❑	❑	❑	❑	❑
I can easily turn my body to look back when reversing my car.	❑	❑	❑	❑	❑
I have trouble turning my neck to check over my shoulder	❑	❑	❑	❑	❑
I can easily get in and out of my car	❑	❑	❑	❑	❑
I feel too tired to drive	❑	❑	❑	❑	❑
My health prevents me from driving	❑	❑	❑	❑	❑

41. Can you identify any things that have caused you to lose your way while driving?

❑ Yes ❑ No

If yes, please describe ....

....

....

In this last section you are asked some more general questions.

42. Age .... years

43. Sex
- ❑ Male
- ❑ Female

44. What type of area do you presently live in?
- ❑ rural
- ❑ town/suburb
- ❑ village/hamlet
- ❑ city
- ❑ other..(please state)

45. How long have you lived in that area?
- ❑ less than 1 year
- ❑ between 5 and 10 years
- ❑ between 1 and 4 years
- ❑ more than 10 years

46. What is your employment status?
- ❑ employed full-time
- ❑ retired
- ❑ employed part-time
- ❑ unemployed
- ❑ house wife/husband
- ❑ .... other

47. How would you rate your health at the present time?
- ❑ Very good
- ❑ Good
- ❑ Average
- ❑ Poor
- ❑ Very Poor

48. On average, how often do you do physical exercise?
- ❑ most days
- ❑ less often than once a week
- ❑ more than once a week
- ❑ never
- ❑ once a week

Lastly, is there anything that you feel could be done to make finding your way while driving easier and safer?...

....

....

....

Thank you very much for completing this questionnaire and for assisting us with our research. Would you please return the completed questionnaire to Loughborough University in the FREEPOST reply envelope provided (no stamp is required).

The address is:

Driving Questionnaire
Department of Human Sciences,
Loughborough University of Technology,
FREEPOST
Loughborough, Leicestershire,
LE11 OBR

Appendix D

Covering Letters for Questionnaire

AA The Automobile Association

Norfolk House Priestley Road
Basingstoke Hampshire RG24 9NY
Facsimile 01256 493698 Telephone 01256 492179

Group Marketing Services

17 November 1995

Dear Sir/Madam,

In order that the AA can provide as efficient and adequate a range of services as possible, we regularly conduct surveys amongst samples of motorists.

This survey is being conducted in association with the Vehicle Safety Research group at Loughborough University of Technology and concerns how people plan their routes while driving.

We would be grateful if you could devote a little time to complete the short questionnaire contained on the following pages and return it in the pre-paid reply envelope supplied, by 4 December 1995.

As this survey is only being conducted amongst a small sample of motorists, your participation is vitally important to ensure that our sample remains representative of motorists as a whole.

This study is being carried out under the Code of Conduct set out by the Market Research Society and in accordance with this code all replies will be entirely anonymous. Each questionnaire is numbered so that reminders can be sent out to those who have forgotten to return the questionnaire to us. Once returned your name and address is removed from our list and your reply will be anonymous and confidential.

Many thanks in advance for you help.

Yours sincerely,

DL Burns

pp Christina Poole
Market Research Project Controller
Group Marketing Services

MARKET RESEARCH SOCIETY
MRS
THIS SURVEY CONFORMS TO THE CODE OF CONDUCT

P.S. In appreciation of your time and effort spent completing this questionnaire we have enclosed a small gift that we hope you will find useful.

Loughborough University of Technology

LOUGHBOROUGH, LEICESTERSHIRE, LE11 3TU

DEPARTMENT OF HUMAN SCIENCES

17 November 1995

Dear Sir/Madam,

The Vehicle Safety Research group at Loughborough University of Technology is conducting a survey of drivers to find out about the strategies people use to plan routes and to find their way while driving.

We would be grateful if you could devote a little time to complete the short questionnaire contained on the following pages and return it in the pre-paid reply envelope supplied, by 4 December 1995.

As this survey is only being conducted amongst a small sample of motorists, your participation is vitally important to ensure that our sample remains representative of motorists as a whole.

This study is being carried out under the Code of Conduct set out by the Market Research Society and in accordance with this code all replies will be entirely anonymous. Each questionnaire is numbered so that reminders can be sent out to those who have forgotten to return the questionnaire to us. Once returned your name and address is removed from our list and your reply will be anonymous and confidential.

Many thanks in advance for you help.

Yours sincerely,

PCBurns

Peter C. Burns
Research Project Controller
Vehicle Safety Laboratory

MARKET RESEARCH SOCIETY
MRS
THIS SURVEY CONFORMS TO THE CODE OF CONDUCT

P.S. In appreciation of your time and effort spent completing this questionnaire we have enclosed a small gift that we hope you will find useful.

Loughborough University of Technology

LOUGHBOROUGH, LEICESTERSHIRE, LE11 3TU

DEPARTMENT OF HUMAN SCIENCES

8 December 1995

Dear Sir/Madam,

A short time ago we sent you a questionnaire on driving. As you may or may not recall, this survey is being conducted by the Vehicle Safety Research group at Loughborough University of Technology and concerns how people plan their routes while driving.

Thank you if you have already taken the time to complete the questionnaire and return it to us. If you feel unable to contribute to this research, please could you pass on the questionnaire to a driver you know who may be more able. It is very important to the success of our survey that we get as many completed questionnaires as possible.

Each of the original questionnaires were numbered so that we could send this reminder out to those who had not yet returned their questionnaire. Once returned your name and address is removed from our list and your reply will be anonymous and confidential. Please return the completed questionnaire in the Freepost reply envelope (no stamp is required).

Many thanks again for you help.

Yours sincerely,

P C Burns

Peter C. Burns
Research Project Controller
Vehicle Safety Laboratory

MARKET RESEARCH SOCIETY
MRS
THIS SURVEY CONFORMS TO THE CODE OF CONDUCT

Appendix E

Modified NASA-R-TLX Rating Scale

Modified NASA-RTLX Rating Scale

Please read the following instructions carefully

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 to 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.

1. Mental Demand
This factor refers to any mental demands placed on you by the driving task, e.g. in planning, thinking, deciding, remembering, looking or searching. Was the driving task mentally easy or demanding?

2. 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?

3. 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.

4. 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.

5. Distraction
This factor refers to the extent to which you felt distracted from the driving task. Safe driving requires you to demonstrate a reasonable amount of vigilance to the events outside the vehicle. Information both inside and outside the car (visual and/or auditory) has the potential to distract you from the driving task.

6. 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		X

	Low	High
Mental Demand		
Mental Effort		
Physical Demand		
Time Pressure		
Distraction		
Stress Level		