SELF-REGULATION OF THE DRIVING BEHAVIOUR OF OLDER DRIVERS

MATTHEW R.J. BALDOCK

Department of Psychology
and
Centre for Automotive Safety Research

at

The University of Adelaide

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ABSTRACT

The aim of this thesis was to examine the extent, and correlates, of self-regulation of driving behaviour among a sample of South Australian older drivers (aged 60 or more). The first of four studies was an analysis of official crash statistics in South Australia over a period of five years. The patterns of crash involvement for South Australian older drivers were found to resemble those reported in the literature for other jurisdictions. Lower levels of crash involvement for older drivers in difficult driving situations (peak hour, rain, darkness) were interpreted as indirect evidence for self-regulation of driving behaviour.

The second study involved pilot testing a measure developed specifically for assessing the visual attention of older adults (the Computerised Visual Attention Test - CVAT). The CVAT assesses visual attention by measuring target detection and reaction time for central and peripheral stimuli, and in conditions requiring selective and divided attention. The third study involved assessing the test-retest reliability, construct validity and predictive validity of the CVAT. It was concluded that the CVAT is a reliable measure of abilities including, but not restricted to, attention, and that it is correlated with on-road driving ability.

The fourth study involved an examination of the driving behaviour and attitudes of 104 drivers aged over 60, with avoidance of difficult driving situations providing an index of self-regulation. These drivers also completed a battery of tests measuring psychological factors, vision, physical functioning, various cognitive abilities, and attention (the CVAT). Ninety participants additionally completed an on-road assessment of driving ability. It was found that older drivers most often avoided reverse parallel parking and driving at night in the rain, while driving alone was avoided least often. Measures of visual attention, medication use and visual acuity were most predictive of levels of self-regulation, while poorer driving ability was only associated

with avoidance of a small number of specific situations. Functional deficits related to poorer driving ability but not to self-regulation included poorer contrast sensitivity, speed of information processing and spatial memory. Such deficits could identify drivers who may need to restrict their driving more than they do.

STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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CHAPTER 1: INTRODUCING THE OLDER DRIVER

1.1 Introduction

A great deal of attention within the road safety literature has recently been devoted to the topic of the "older driver", defined here as those drivers aged 65 or more. This focus of interest on older drivers is primarily due to projected increases in the number of older drivers over the next 20 to 30 years, and the fact that older drivers have a higher relative crash risk per kilometre driven than other drivers in all but the youngest age groups. Much research has focused on the factors that are related to this increased crash risk and attempts have been made to develop screening tests for identifying older drivers with an elevated risk of crashing. An increasing recognition of the benefits for older adults of maintaining mobility has also led to interest in the possibility that older drivers may be able to reduce their own crash risk by restricting their driving. This "self-regulation" by older drivers may include changes not only in the amount of driving done but also in the conditions in which they drive. If older drivers are able to self-regulate effectively, then any screening of older drivers could focus only on those who are affected by declines in functioning that are expected to considerably increase crash risk.

This thesis examined the self-regulation of driving behaviour of older drivers in South Australia. The likely efficacy of self-regulation as a means by which older drivers can safely extend their driving lives was determined by assessing the degree to which restrictions of driving by a sample of older adults were consistent with their functional and driving abilities. That is, the thesis examined whether drivers with decrements in functional or driving abilities restricted or altered their driving accordingly.

As background to the study of self-regulation, the literature on older drivers was reviewed, beginning with a discussion of the aging of the driving population and the crash risk of older drivers. This is followed by an analysis of official crash statistics over a five year period for older drivers in South Australia (Chapter 2), which was undertaken to determine whether the crash patterns of South Australian older drivers are similar to those reported in the literature for other regions. Chapter 3 provides a review of the literature concerned with risk factors for older driver crash involvement, with a particular focus on age-related increases in the prevalence of medical conditions and age-related declines in functional abilities. Chapter 4 then discusses responses to the elevated crash risk of older drivers. Specifically, it discusses screening of older drivers to identify those with an increased crash risk, and previous research into older driver self-regulation.

In order to examine the relationships between functional abilities and self-regulation, it was necessary to develop a computerised test of visual attention. This process is described in Chapter 5. Chapter 6 then provides the methodology used for a large-scale study into self-regulation, and the methodology for a study conducted to assess the validity of the visual attention test. The results of this validation study for the visual attention test are presented in Chapter 7, while the following three chapters provide the results of the study of self-regulation. Chapter 8 presents analyses of the relationships between functional abilities and driving ability among a sample of older drivers, Chapter 9 presents a summary of the driving attitudes and behaviour of these older drivers, and Chapter 10 provides analyses of the relationships between both functional and driving abilities, and self-regulation. Finally, Chapter 11 provides a summary and synthesis of the findings of the previous chapters and offers the overall conclusions of the thesis.

To begin with, it is necessary to provide a background to the current interest in the issue of older drivers. The following sections describe the causes of the likely increases in the number of older drivers in the near future, and also provide details of the crash patterns of older drivers.

1.2 Increases in Older Drivers

One of the main reasons for a growing interest in older drivers is the projected future increase in the number of older drivers on the road. This increase is related to three factors. First, the percentage of elderly persons in the population is increasing; secondly, there are increases in the proportion of people who have driver's licences in each successive cohort; and thirdly, successive cohorts of older licence holders are continuing to drive for longer than previous cohorts (Hakamies-Blomqvist, 1996).

1.2.1 An Aging Population

Increases in the proportion of elderly persons in the population can be attributed to increasing life expectancy and declining birth rates (OECD, 1985). One additional factor that is expected to produce substantial increases in the population of elderly persons in the coming years is the movement into the older age bracket of the so-called "baby boom" generation born between 1946 and 1964 (Klavora & Heslegrave, 2002; OECD, 1985).

Luszcz (1999) provides data demonstrating an increase in the proportion of those aged over 65 in the Australian population from 1861 to the present day. This increase has occurred steadily over that time, with the older age group rising from 1% of the total population in 1861 to 4% by the turn of the twentieth century, to 8% by the middle of the century, and to 12% in 1996. Moreover, the population in South Australia has a higher proportion of older residents than the national average, with 13.8%

recorded in 1996. Luszcz also reported projections made by the Australian Bureau of Statistics that the proportion of older residents in Australia will soon increase at a much faster rate than has been the case in the past, with the proportion increasing to 16% by 2016 and 24% by 2051.

These figures are consistent with those reported in a recent OECD report predicting that the proportion of people aged over 65 in Australia will be around 18% in 2020 and 25% in 2050 (OECD, 2001). The report also claimed that the largest increases would be among the very old, namely those over 80. The proportion of the Australian population who were over 80 in 2000 was 3.1%. This percentage is expected to double by 2030 and triple by 2050 (OECD, 2001).

Similar predictions have been made for the United States. Kostyniuk, Shope, and Molnar (2000), for example, reported that 10% of the population in the USA were over 65 in 1977, 14% were over 65 by 1997, and this figure was expected to be 20% by 2020. In addition, Hu, Jones, Reuscher, Schmoyer, and Truett (2000) reported that those aged over 85 are the fastest growing segment of the USA population. Similar findings of an aging population and projections for further rapid increases in the elderly proportion of the population have also been made in Western Europe and Japan (Fildes, 1997).

1.2.2 Increasing Licensure Among Older Residents

An additional factor that will lead to substantial increases in the number of elderly drivers on the road in the near future is the increase, with each successive cohort, in the percentage of eligible citizens who hold a driver's licence. This increase in licensure rates is expected to have a greater effect on the number of older drivers in future years than increases in the elderly population (Hull, 1991; Maycock, 1997).

Burkhardt, Berger, Creedon, and McGavock (1998) have predicted that the number of driver's licences held by older adults in the USA in 2030 will be over double that held in 1996 and that the biggest increases will be among those aged over 85. Eberhard (1996) reported predicted increases in licensed older drivers and added that growth in female licences among older drivers will exceed the growth in male licences. In support of this, a licensing survey conducted in Melbourne, Australia (reported in OECD, 2001) found that, among those aged over 65, 75% of men and 40% of women were licensed to drive, while for those aged 45 to 54, nearly 100% of men and 90% of women held licences, demonstrating not only an increase in licensure in more recent cohorts but also a disproportionate increase in female licensure. These increases in older female drivers due to increasing licensure among females in younger cohorts are expected to occur throughout the Western world (Hakamies-Blomqvist, 1996; Laapotti, 1991; Weinand, 1996).

1.2.3 Older Drivers Driving More and for Longer

A final reason for expected increases in the numbers of older drivers on the roads of developed countries is that older drivers in more recent cohorts are driving longer distances and giving up driving at a later age than their predecessors (Fildes, 1997; Hakamies-Blomqvist, 1996; Hu et al., 2000; Jette & Branch, 1992; Stutts, 2003). Between 1983 and 1995, the annual mileage of American drivers increased by 25% but for those over 65, it increased by 44% (Lyman, Ferguson, Braver, & Williams, 2002). In another North American study, Burkhardt et al. (1998) predicted substantial increases in mileage among older drivers from 1990 to 2020, with increases among men expected to be 465% and among women 500%.

These increases in the distances travelled by licensed older drivers are related to increased social activities, longer participation in the workforce, and increased access to a car among more recent cohorts (Fildes, 1997; Keskinen, Ota, & Katila, 1998; OECD, 2001). Another contributor to the predicted increases in mileage among older drivers is that cohorts tend to maintain the same driving habits throughout their lives (Hakamies-Blomqvist & Peters, 2000) and that reliance on a motor vehicle for transport tends to be maintained even when a driver reaches his or her 70s and 80s (Collia, Sharp, & Giesbrecht, 2003; Jette & Branch, 1992). The so-called "baby boom" generation, soon to enter old age, has been notable for its reliance on motor vehicles for transport and for driving much longer distances than previous cohorts (OECD, 2001).

1.2.4 Summary

The evidence points unequivocally toward substantial increases over the next 20 to 30 years in the amount of driving that will be done in developed countries by drivers aged over 65. Increases in the population aged over 65 will combine with increased driver licensure among more recent cohorts, especially among women, and increased driving done (increased mileage) by those with licences, to ensure that the distances driven by older drivers in the future will far exceed those being driven at present. With these expected increases in the amount of driving being done by drivers over 65, the effect of aging on driving ability has become a major road safety issue in recent years. The following section provides details of the relationship between age and crash rates, with a particular emphasis on the crash involvement of the "older driver".

1.3 The Crash Involvement of the Older Driver

1.3.1 Raw Crash Numbers

When considering the crash involvement of any particular group, the first data that are inspected are those relating to raw crash numbers. The raw crash numbers by age group indicate that older drivers have fewer crashes than drivers in younger age groups. This has been found in Australia (Federal Office of Road Safety, 1996; Fildes, Corben et al., 1994; RSC, 2001; Ryan, Legge, & Rosman, 1998), the USA (Evans, 2000; Lyman et al., 2002; NHTSA, 2002), and Europe (Maycock, 1997; OECD, 1985, 2001).

Ryan et al. (1998), for example, looked at involvement in police-reported crashes in Western Australia in the years 1989 to 1992 inclusive, and found that the extent of crash involvement declined with each successive five-year age group beyond the 20 to 24 year old age group. Drivers under the age of 25 were involved in 35% of police-reported crashes, while those aged over 70 were involved in only 3%. National data for Australia collected between 1993 and 1995 showed that crash involvement of older drivers is higher when only crashes in which a driver was fatally injured are considered, with 19% of drivers killed in these years being aged over 60 (Federal Office of Road Safety, 1996). However, this was still less than the percentages for those aged 15 to 24, 25 to 39 and 40 to 59.

In the USA in 2001, crash involvement declined with age beyond the 25 to 34 age group, with those over the age of 65 being involved in fewer crashes than any age group of driving age (NHTSA, 2002). The percentage of crash-involved drivers over 65 was 7.6%, compared with 21.0% for those aged 25 to 34. For fatal crashes, drivers aged over 65 were involved in more crashes than those aged 55 to 64 and 21 to 24 but less than all other age groups. Drivers over 65 were involved in 11.4% of fatal crashes, compared to 20.5% for those aged 25 to 34.

Data from the late 1990s presented in a recent OECD (2001) report showed that, in Great Britain, the Netherlands and Spain, absolute involvement in crashes resulting in injury declined with age after peaking in the 25 to 34 year age group. Drivers over 65 were involved in 5.3% of crashes in Great Britain, 7.6% in the Netherlands and 4.3% in Spain. The different results produced by separate analyses of fatal crashes are illustrated by comparing the data in the OECD report with data for fatalities to car occupants from 1990 to 1994 presented by Maycock (1997). The comparable figures for these three countries were 16.7% for the United Kingdom, 16.6% for the Netherlands and 8.2% for Spain, again indicating that the proportional involvement of older drivers in crashes increases when only fatal crashes are considered.

Together, these findings demonstrate that, relative to other age groups, older drivers are involved in fewer crashes. Even when fatal crashes are examined alone, crash involvement declines with age in absolute terms. In other words, given a crash, the likelihood that an older driver was involved is relatively small. Some authors have also pointed out that, given the death of an older person, the likelihood that it was due to a road crash is relatively small. For example, Evans (2000) stated that from the 20s onwards, the proportion of deaths attributable to road crashes declines with age, as people are increasingly more likely to die from other causes. Figures quoted by Evans indicate that road crashes account for 20% of deaths in the teenage years and twenties, less than 1% for those over 65, and less half a percent for those over 80. Hu et al. (2000) pointed out that, in contrast to younger drivers, heart disease and cancer are far bigger risks for older drivers than crash involvement. However, crashes are common causes of traumatic injuries in older people. Barancik et al. (1986) reported that, in the USA, road crashes were the leading cause of injury-related fatalities for those aged 65-74 and were second only to falls for those over 75.

Despite this decline in crash involvement with age, an increased susceptibility to injury and an increased recovery time mean that the costs to society of treating injuries in older drivers are substantial. For example, a study by the USA Department of Transportation (1997) found that a third of health care costs resulting from serious injury crashes were spent on the elderly.

1.3.2 Crashes Per Head of Population

Differences between different age groups in terms of population numbers can lead to raw crash data exaggerating the crash risk of drivers in groups with a large population and concealing any increased crash risk of drivers in groups with a small population. Therefore, a better indication of the crash risk of drivers in different age groups is provided by calculating crash involvement rates per head of population. As with raw crash numbers, these crash rates per capita reveal that with increasing age there is a decline in crash involvement. Again, this has been found in Australia (RSC, 2001; Ryan et al., 1998), the USA (Eberhard, 1996; Lyman et al., 2002) and Europe (Hakamies-Blomqvist, 2002; Maycock, 1997; OECD, 2001).

Ryan et al. (1998), for example, found that involvement as a driver in police-reported crashes in Western Australia from 1989 to 1992 declined with each successive age group, starting at 89 crashes per 1,000 population per year for those aged 17 to 19 and declining to 8 crashes per 1,000 population per year for those aged over 79. In the USA, Lyman et al. (2002) found that police-reported crashes per head of population declined with increasing age, with a rate of 102 crashes per 1,000 population for those aged 16 to 19 compared with 20 for those aged over 79. The total rate for those aged over 64 was 26, compared with 66 for those aged from 16 to 64. In Great Britain in 1998, drivers aged over 60 comprised 20.5% of the population but only 8.8% of the drivers injured in crashes and 13.8% of the drivers seriously injured in crashes, while those over 80 comprised 4.6% of the population, 1.1% of drivers injured in crashes and 2.5% of the drivers seriously injured in crashes (OECD, 2001).

As indicated in section 1.3.1, older drivers' crash involvement rates are higher when only fatal crashes are considered (Eberhard, 1996; Lyman et al., 2002; OECD, 2001). Lyman et al. (2002), for example, found in the USA that the decrease with age in crash involvement per head of population was not as pronounced when fatal crashes only were analysed. The rate of fatal crashes per capita was significantly higher for those aged over 64 than for those aged from 50 to 64 but lower than for all age groups between 16 and 44. In Great Britain, those aged over 60 comprised 20.5% of the population and 20.6% of drivers fatally injured in road crashes, while those aged over 80 comprised 4.6% of the population and 5.6% of the drivers fatally injured (OECD, 2001).

1.3.3 Crashes Per Licensed Driver

Although it is useful to adjust crash involvement data according to differences between the populations of different age groups, the resulting crash rates do not take into account differences between age groups in the number of licensed drivers. As extent of licensure does change with age, declining among those over 65 (Maycock, 1997; OECD, 2001; Ryan et al., 1998; Transport SA, 2003), it is important to analyse relative crash involvement in different age groups by looking at crashes per licensed driver. Such analyses have revealed increases in crash rates among the oldest drivers, although these crash rates are still lower than those of the youngest age groups.

Ryan et al. (1998) found in Western Australia that crash involvement rates per 1,000 licensed drivers per year decreased with age until a low of 23.7 for those aged 70 to 74 but increased to 46.4 for those aged 75 to 79. However, this was lower than the crash rates for those aged 17 to 19 (123.9) and 20 to 24 (72.8).

Lyman et al. (2002) looked at police-reported road crashes in the USA in 1995 and found that crash rates per 1,000 licensed drivers decreased with age until reaching a low of 34 among those aged 65 to 69 but increased thereafter to 38 for those aged over 79. For those aged over 64, the crash rate was 35, compared to a rate of 66 for those aged from 16 to 64. Fatal crashes, again, did not decrease as much with age, reaching a minimum at a younger age (0.17 per 1,000 drivers for those aged 55 to 59) before increasing to 0.37 for those aged over 79. Only those aged 16 to 24 had a higher fatal crash rate than those aged over 79. The difference between those over 64 and those younger was smaller for fatal crashes, with the fatal crash involvement per 1,000 drivers being 0.24 for those aged over 64 and 0.27 for those aged 16 to 64. Similar findings regarding crashes per licensed driver have been reported in other North American studies (Dellinger, Langlois, & Li, 2002; NHTSA, 2002; Stutts & Martell, 1992).

Figures for injury crashes in 1998 in European countries are similar to those in the USA and Australia (OECD, 2001). In Great Britain, the Netherlands and Spain, the lowest crash rates per licensed driver were for drivers aged between 55 and 74, with small increases for older age groups (> 74). In each of these countries, drivers in the youngest age groups had the highest crash rate per licensed driver (OECD, 2001).

1.3.4 Crashes Per Distance Driven

Analysing the crash rates of different age groups by adjusting for licensure levels provides a better indicator of crash risk than rates adjusted only for population differences but such rates do not take account of the fact that older drivers are known to drive fewer kilometres per year than drivers in other age groups (Collia et al., 2003; Lyman et al., 2002; Maycock, 1997; OECD, 2001; Ryan et al., 1998). To take these differences in driving exposure into account, it is necessary to calculate crash rates per kilometre driven for the different age groups. When this is done, it reveals an increased crash risk at the two ends of the driver age range. That is, young drivers and old drivers have an increased risk of crashing per kilometre driven than middle-aged drivers. This finding, referred to as the ‘U-shaped curve’ of crash risk by age, is so consistent across different jurisdictions that Frith (2002, p205) has called it ‘ubiquitous’.

When Ryan et al. (1998) adjusted Western Australian police-reported crash involvement figures by kilometres driven per year in different age groups, they found that crash rates varied little between the ages of 25 and 74 but were elevated among drivers outside of this range. The highest crash rate was for those aged 17 to 19 (1,414 crashes per 100 million kilometres driven), followed by those for drivers aged over 79 (1,038) and drivers aged 75 to 79 (1,020). Drivers aged 20 to 24 had the fourth highest crash rate (766). The crash rate per kilometre driven for those aged over 74 was over three times higher than that for the group with the lowest crash rate, those aged 45 to 49 (329). National Australian data for fatal crash involvement showed that fatal crash rates per kilometre driven by age group also produced a U-shaped curve, with those aged 45 to 49 being the safest drivers (Federal Office of Road Safety, 1996). According to these data, fatal crash risk per kilometre driven was elevated for those aged under 30 and over 64, with the highest crash risk being for drivers aged over 80.

Frith (2002) reported casualty crash rates per kilometre driven in New Zealand and showed that crash rates were lowest again for those aged 45 to 49 and highest for those aged 15 to 19. The age group with the second highest crash risk was the group aged over 79. The U-shaped curve for the New Zealand figures included substantial increases in casualty crash rates for those over 69.

Lyman et al. (2002) examined USA crash data and found that police-reported crash rates per mile driven were elevated for those under 30 and over 69, with the highest rate being for those aged 16 to 19 (2,434 crashes per 100 million miles driven), followed by those aged over 79 (1,466). Those over 64 were involved in 563 crashes per 100 million miles driven compared with 522 for those aged 16 to 64. The figures for fatal crashes were similar with respect to age, except that the crash rate per mile driven for those over 79 (14.5) was higher than that for those aged 16 to 19 (10.0).

Maycock (1997) reported that findings in Europe have echoed those in Australasia and the USA, with U-shaped curves of crash risk by age being found for fatal crash figures in the UK, West Germany and the Netherlands, and for serious injury and fatal crashes combined in Denmark. Many other studies around the world have reported that crash risk per unit of driving exposure is highest for the youngest and oldest drivers, with relatively lower risk reported for middle-aged drivers (Brorsson, 1989; Cerelli, 1989; Diamantopoulou, Skalova, Dyte, & Cameron, 1996; Evans, 1988, 2000; Fildes, Corben et al., 1994; Graca, 1986; Hu et al., 2000; Maleck & Hummer, 1987; Massie, Campbell, & Williams, 1995; OECD, 1985; Stutts & Martell, 1992; Waller, House, & Stewart, 1977; Williams & Carsten, 1989).

Crash rates analysed according to age group, therefore, show that older drivers have relatively few crashes in absolute terms and per head of population but show increased rates per licensed driver and, especially, per unit of driving exposure. This seems to suggest that the driving ability of older drivers is deficient compared with that of other age groups. However, a number of authors (e.g. Hakamies-Blomqvist, 1998; Maycock, 1997; OECD, 2001) have argued that a large component of the increased crash risk of older drivers per kilometre driven is due to factors not linked to age-related declines in driving ability. These factors include cohort effects, frailty effects and low mileage effects, each of which is discussed in the following sections.

1.3.5 Changes Across Cohorts in Older Drivers' Crash Risk

One explanation for the increased crash risk among older drivers is that it represents a cohort effect, such that older cohorts may have had an increased risk of crashing even at a younger age. Increases in risk reported in cross-sectional comparisons may be due to the failure to control for these cohort effects (Hakamies-Blomqvist, 1996). This explanation is based on the findings of longitudinal studies that earlier cohorts of older drivers had higher rates of crash involvement than more recent cohorts (Evans, 1993; Li, Shahpar, & Grabowski, 2001; Lyman et al., 2002; Stamatiadis & Deacon, 1995; Stutts & Martell, 1992). Cohort differences in the risk of crashing among older drivers have even been found over periods of only five to ten years (Barr, 1991; Dellinger et al., 2002).

The main reasons advanced for these declines in crash risk for younger cohorts are related to differences in driving experience (Maycock, 1997). More recent cohorts have learnt to drive at a younger age compared to older cohorts, many of whom learnt to drive as adults. Younger cohorts have also experienced driving throughout their lives in highly automobile-dominated times, while many of today's older drivers have had to adjust to major changes in the traffic system throughout their driving careers, initially learning to drive with few other vehicles on the road but now faced with multi-lane highways that are dense with traffic (OECD, 2001; Stamatiadis & Deacon, 1995). Also, many older drivers obtained their licences prior to the requirement of passing a detailed on-road test.

Although it is clear that cohort effects exist, Stamatiadis and Deacon (1995, p443) found that cohort effects were "small" compared with time-related effects. They concluded that even if older drivers' crash risk per unit of driving exposure continues to decline in the future, they would remain a "high-risk component of the driving population."

1.3.6 The "Frailty Bias"

Another explanation for the over-representation of older drivers in reported crashes is that their greater susceptibility to injury makes it increasingly likely that a crash featuring an older driver will result in an injury and be serious enough to be reported to police. This, in turn, means an increased likelihood that the crash will feature in official road crash databases (Evans, 1988, 2000; Hakamies-Blomqvist, 1998, 2002, 2003; Maycock, 1997; Pike, 1989). Hakamies-Blomqvist (2002, p33), for example, argued that when comparing the crash rates of drivers in different age groups, it must be assumed that their crashes are "represented in a similar manner" in the database used, so that similar crashes from both groups are included. Whenever injury is used as an inclusion criterion for a crash database, it is possible that older drivers' crashes more often meet the criterion and are thereby included in the database more frequently than the crashes of other groups.

A number of studies have attempted to quantify the greater injury or fatality risk that affects older road users. Evans (1991b) analysed fatality risk by age and gender and found that, for a crash of any given severity, an 80 year old male was four times more at risk of dying than a 20 year old male and three times more at risk than a 20 year old female. It also was concluded that for each year over 20, the fatality risk of a male in a road crash increases by 2.3% while that for a female increases by 2%. Figures from a study in the UK (reported in OECD, 2001) have also demonstrated the increased likelihood of injuries proving fatal for older road users, whether they are car occupants or pedestrians. The ratio of fatal to non-fatal injuries for those aged 60 was 1.75 times that for those aged 20 to 50. This relative risk of 1.75 for those aged 60 increased to 2.6 for those aged 70, and to between 5 and 6 for those aged 80 or more. Many other studies have also found that the rates of injuries and post-traumatic complications, and time taken for recovery increase for those aged 65 or over (Baker, O'Neill, Ginsberg, & Li, 1992; Fildes, 2002; G. McCoy, Johnstone, & Duthie, 1989; Peek-Asa, Dean, & Halbert, 1998; Sjogren, 1994; Transportation Research Board, 1988; Underwood, 1992; Viano, Culver, Evans, Frick, & Scott, 1989).

The extent to which the over-representation of older drivers in crash figures is related to greater injury susceptibility has been assessed in a number of studies. The consensus is that this frailty bias does inflate the crash involvement of older drivers but is not sufficient to account for all of the increased risk. An Australian study (Federal Office of Road Safety, 1996) used the relationship between age and susceptibility to injury calculated by Evans (1991b) to adjust fatal crash risks by age group. This statistical adjustment reduced the elevated risk of older drivers but did not eliminate it. Those aged 65 to 69 still had 2.5 times the risk of those aged 45 to 49, with an even higher risk remaining for those aged over 69. Those aged over 85 still had the highest fatal crash risk of any age group. Maycock (1997) also used the work of Evans to analyse fatal crash rates in a number of European countries. He concluded that half of the increased fatal crash risk of older drivers was due to their relative physical frailty. Hakamies-Blomqvist (1993) found that older drivers were over-represented in fatal crashes at intersections in Finland and investigated whether this was due to older drivers being more likely to be fatally injured in these crashes or having an increased likelihood of being involved in them. As the extent of damage sustained by vehicles (a measure of severity of the impact) in the crashes of young and older drivers was found to be comparable, it was concluded that older drivers were indeed over-represented in intersection crashes. This finding replicated those of other studies (Hauer, 1988; Viano, Culver, Evans, & Frick, 1990).

Studies in the USA have produced similar results. Evans (2000) used his own previous work on frailty to adjust fatal crash rates from 1994 to 1996. He found that, per licensed driver, there was an increase in crash risk over age 70, while per unit of driving exposure, there was an increase in crash risk for drivers over 60, although the increased risk did not reach the level of risk among younger drivers. Dellinger, Langlois, and Li (2002) analysed fatal crash involvement rates among older drivers to determine the extent to which they were determined by the increased risk of a fatality in the event of a crash, increased crash risk, or driving exposure. Comparing these factors for drivers aged 65 to 74, 75 to 84, and over 84 to those aged 55 to 64, it was found that the strongest determinants of changes with age in fatal crash risk were risk of crashing and driving exposure. Increased risk of a fatality given a crash made the smallest contribution.

1.3.7 The "Low Mileage Bias"

Another factor that may contribute to the increased crash involvement of older drivers on a per kilometre driven basis is the fact that older drivers tend to drive fewer kilometres than drivers in younger age groups. This is of relevance because it has previously been established that, irrespective of age, gender or other demographic characteristics, drivers who drive less record more crashes per kilometre driven than those who drive more (Daigneault, Joly, & Frigon, 2002b; Hakamies-Blomqvist, 1998, 2002, 2003; Hu et al., 2000; Janke, 1991; Maycock, 1997; OECD, 2001). Janke (1991), for example, found that low mileage drivers were involved in more crashes per mile driven than those with high mileage, and attributed this to the different levels of mileage driven by these two groups on roads where there are few crashes per mile. Specifically, Janke noted that there were 2.75 times more crashes per mile driven on non-freeways than freeways. Those who drive longer distances, Janke argued, are likely to amass much of their elevated yearly mileage on freeways, which feature a division of traffic travelling in different directions and limited access from other roads.

Eberhard (1996) pointed out that older drivers do disproportionately more of their driving on local roads, rather than freeways, and so encounter disproportionately more intersections, congestion, confusing visual environments, signs, and signals. Similar to Janke (1991), Hakamies-Blomqvist (2002) claimed that drivers who drive long distances per year tend to travel long distances on freeways without encountering intersections, where there is a greater risk of crash involvement. By driving further on freeways, high mileage drivers are able to improve their crash risk per mile ratio because they are driving long distances with few situations of potential traffic conflict.

Based on this low mileage bias, Hakamies-Blomqvist (2003) claimed that, in order to make fair comparisons of crash risk by age group, it is necessary to control for mileage differences. A comparison of drivers aged 26 to 40 and those over the age of 65 was therefore conducted with the drivers being split up into three mileage groups using the 20th percentile of mileage for older drivers to define the low mileage group and the middle 60% of older drivers to define the middle mileage group. The highest 20% of older drivers, in terms of mileage, were used to define the high mileage group. It was found that, within each of these mileage groups, older drivers recorded lower crash numbers per distance driven than the corresponding younger group, despite the overall analysis revealing a higher level of crash involvement per distance driven for the older drivers. This resulted from there being more older drivers in the low mileage group, who recorded higher crash involvement than those within the higher mileage groups. Hakamies-Blomqvist (2003) concluded that this demonstrated that the increased risk of crashing per distance driven exhibited by older drivers is an artefact of lower driving exposure.

One problem with this analysis is that drivers are not randomly assigned to different levels of yearly mileage. Drivers choose for themselves how much driving they do and it is possible that many older drivers choose to drive less on the basis of perceived deficits in driving-related functioning. In Hakamies-Blomqvist's (2003) analysis, those older drivers in the high mileage group (above the 80th percentile) are likely to have the highest levels of functioning for their age group, while the comparison group of young drivers is unlikely to be the highest 20%, in terms of functioning, of their age group. Similarly, young drivers who drive as little as those older drivers in the lowest 20% of the older age group may be a group with certain characteristics (e.g. medical conditions or functional disabilities) that predispose them to a higher crash risk, irrespective of the increased risk resulting from greater exposure to intersections that is used by Hakamies-Blomqvist to explain differences in crash rates.

Regardless of the analysis above, it does appear that part of the increased crash risk per kilometre driven of older drivers may be due to the greater relative exposure of lower mileage older drivers to traffic conflict at intersections. Maycock (1997, p63), noting that older drivers often deliberately reduce their driving, described as "perverse" the possibility that one effect of this could be an increased crash rate per kilometre driven. He added that it "would be ironic indeed, if older drivers were to be singled out for remedial attention on the per kilometre basis because of their compensatory behaviour" (Maycock, 1997, p63). Maycock claimed, nonetheless, that the higher fatal crash rates of older drivers induced by greater susceptibility to injury were enough to justify attention being given to older drivers.

1.3.8 Future Projections for Older Driver Crash Involvement

Given the predicted increase over the next 20 to 30 years in the amount of driving that will be done by older drivers, a number of studies have provided estimates of the effects that this will have on older driver crash involvement. One Australian study predicted that in 2025 there would be a 286% increase in road fatalities for those aged over 65 compared to 1995 (Fildes, Fitzharris, Charlton, & Pronk, 2001). The Federal Office of Road Safety (1996) analysed driver fatalities from 1986 to 1994 and found that, whilst fatalities decreased by over 20% for all age groups below 60, they increased for the over 59 group. The proportion of fatalities was predicted to increase from 9% in 1994 to 13% in 2015 for those aged 60 to 69, and from 10% to 16% over the same period for those aged over 69.

Lyman et al. (2002) analysed USA crash rates from 1983, 1990 and 1995, and calculated expected rates for 2010, 2020 and 2030. The authors expected that decreases in injury susceptibility in later cohorts would be counteracted by increases in licensure and kilometres driven. They predicted that, compared to 1999, crash numbers for drivers overall would increase by 34% by 2030, while fatalities would increase by 39%. For older drivers, it was predicted that crashes would increase by 178% and fatalities by 155%. In 1999, older drivers accounted for 8% of police-reported crashes but Lyman et al. predicted this proportion would increase to 16% by 2030. For fatal crashes, it was predicted that the proportion of 14% in 1999 would increase to 25% by 2030. Other USA studies have also predicted increases in older driver crashes (Burkhardt et al., 1998; Hu et al., 2000).

Although making sound predictions for the future is difficult, studies have consistently estimated that the number of crashes involving elderly drivers will rise in absolute numbers and as a proportion of the crash numbers for the whole population. This highlights the importance of developing methods for minimising the crash and injury risk of older drivers.

1.3.9 Crash Characteristics

In addition to differences in the rates of crash involvement between drivers in different age groups, there are also differences in the *characteristics* of crashes that typically occur. This section provides details of the crash characteristics found to be over-represented in the crashes of older drivers.

As discussed in the section concerned with the "frailty bias" (section 1.3.6), older road users are more susceptible to injury in the event of a crash than younger road users and, because of this, older drivers are often over-represented in crashes that result in severe injuries (Cerelli, 1989; Evans, 1988; Lyman, McGwin Jr, & Sims, 2001; McKelvey & Stamatiadis, 1989; Ryan et al., 1998). Ryan et al. (1998), for example, found that 0.3% of police-reported crashes in Western Australia were fatal but that the percentage was 0.7 for drivers aged 60 to 64, 0.6% for drivers 65 to 69, 1.1% for drivers 70 to 74, 1.4% for drivers 75 to 79 and 2.0% for drivers over 79. With the exception of the 65 to 69 age group, all of these percentages differed significantly from the level of 0.4% for drivers in the baseline group (those aged 45 to 49). Drivers over 69 were also over-represented in crashes resulting in hospitalisation, compared to the baseline group. Similarly, in the USA in 1995, the percentage of crashes that were fatal was less than 0.4 for drivers aged 45 to 49 but was over 0.5 for all age groups over 65, reaching 1.0 for drivers aged over 79 (Lyman et al., 2002).

One of the most commonly reported crash types that is over-represented among older drivers is that of multiple vehicle crashes at intersections (Broughton, 1988; Campbell, 1966; Cerelli, 1989; Cooper, 1990b; Council & Zegeer, 1992; Daigneault et al., 2002b; Fontaine & Gourlet, 1992; Hakamies-Blomqvist, 1993; Hauer, 1988; Holland & Rabbitt, 1994; Hu et al., 2000; Keskinen et al., 1998; Maycock, 1997; McKnight, 1996; OECD, 1985, 2001; Partyka, 1983; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Ryan et al., 1998; Stamatiadis & Deacon, 1995; Stamatiadis, Taylor, & McKelvey, 1991; Staplin, Gish, Decina, Lococo, & McKnight, 1998a; Staplin & Lyles, 1991; Taylor, Ahmad, & Stamatiadis, 1994; Viano et al., 1990). In order to ascertain the reason for this over-involvement of older drivers in intersection crashes, researchers have analysed the types of intersections at which these crashes typically occur, the types of crashes occurring, and the types of errors usually committed prior to the occurrence of crashes. These analyses have revealed that older drivers tend to be over-represented in crashes:

- at both uncontrolled and sign-controlled intersections (Cooper, 1990b; Hu et al., 2000; Preusser et al., 1998; Stamatiadis et al., 1991),
- while performing turning manoeuvres, especially turns across oncoming traffic (Brainin, 1980; Cooper, 1990b; Council & Zegeer, 1992; Daigneault et al.,

2002b; Eberhard, 1996; Malfetti & Winter, 1987; Preusser et al., 1998; Stamatiadis, Taylor, & McKelvey, 1990; Strano, 1994),

- after having disobeyed traffic signs or signals (Brainin, 1980; Cooper, 1990b; Council & Zegeer, 1992; Eberhard, 1996; Foley, Wallace, & Eberhard, 1995; Partyka, 1983; Preusser et al., 1998; Schlag, 1993; Waller et al., 1977), and
- after having failed to give way to other traffic (Brainin, 1980; Cooper, 1990b; Council & Zegeer, 1992; Eberhard, 1996; Foley et al., 1995; Holland & Rabbitt, 1994; Keskinen et al., 1998; Kline et al., 1992; McKnight, 1996; Partyka, 1983; Preusser et al., 1998; Stamatiadis et al., 1991; Stamatiadis et al., 1990; Taylor et al., 1994; Waller et al., 1977).

This over-representation of older drivers in intersection crashes and the corresponding catalogue of apparent intersection-specific errors could have a number of causes. Preusser et al. (1998) pointed out that the relative increase in intersection crashes for older drivers could be due to increases in intersection-specific driving errors, to changing driving patterns that result in older drivers being exposed disproportionately to situations and conditions (e.g. daylight hours) when multiple vehicle crashes at intersections are more likely to occur, or to physical frailty that increases the likelihood of injury in low speed intersection crashes and, consequently, that increases the likelihood of the crashes being recorded in official databases. Most attention has been given to the explanation of intersection-specific errors that result from declines in various aspects of functioning.

One aspect of functioning that has been identified as being a factor in older driver crashes at intersections is attention. Hakamies-Blomqvist (1993) nominated divided attention (discussed later in section 3.4.4), in particular, to be implicated in older driver intersection crashes. She claimed that drivers can compensate for declines in attentional abilities by driving more slowly, thereby allowing more time for decision making, but that this is not possible at intersections. The decisions that drivers need to make at intersections are not self-paced but must be made in a time frame that is determined by changes in traffic lights and the movements of other traffic. Preusser et al. (1998) also claimed that older drivers have trouble with divided attention, such as making decisions under time pressure while coping with threats coming from a cluttered peripheral visual field (e.g. cars, pedestrians, traffic signal changes). The authors claimed older drivers need more time than their younger counterparts to process sensory inputs, decide on a course of action, and implement that decision. A number of other authors have also concluded that the over-involvement of older drivers in intersection crashes is related to the need to make complex decisions in a limited time frame while dividing attention between a number of concurrent tasks (OECD, 2001; Staplin et al., 1998a; Stutts, 2003).

Another ability that declines with age and is thought to be important for the successful negotiation of intersections is that of judging the speed of other vehicles that are approaching the intersection. Staplin and Lyles (1991) looked at the age of at-fault drivers at intersections in Michigan and found that at-fault drivers who were executing turning manoeuvres were more likely to be older drivers, while at-fault drivers travelling straight through the intersection were more likely to be young. The authors concluded that older drivers had little trouble with intersections when other vehicles were approaching from the side but had difficulty turning in front of oncoming traffic. This was attributed to the greater difficulty associated with estimating the arrival time of vehicles approaching from directly ahead, compared to vehicles approaching from the side, and the lesser ability of older drivers to detect angular movement.

In addition to an over-involvement in intersection crashes, older drivers are more likely than younger drivers to be found responsible for the crashes in which they are involved (Cooper, 1990b; Cooper, Tallman, Tuokko, & Beattie, 1993a; Elliott, Elliott, & Lysaght, 1995; Fontaine & Gourlet, 1992; Hakamies-Blomqvist, 1993; Hu et al., 2000; Maycock, 1997; McKelvey & Stamatiadis, 1989; Partyka, 1983; Preusser et al., 1998; Sjogren, Bjornstig, Eriksson, Sonntag-Ostrom, & Ostrom, 1993; Stamatiadis & Deacon, 1995; Stamatiadis et al., 1990; Verhagen, 1995; Viano et al., 1990). This tendency for older drivers to be responsible for the crashes in which they are involved, however, has been called into question by some authors.

One objection to this common finding is that the judgements regarding responsibility made by police officers or insurance assessors may be biased against older drivers, such that older drivers are more likely to be found responsible for their crashes (Fildes, 1997; OECD, 1985). Hakamies-Blomqvist (1993, p25) noted that "authorities may be biased against the very young and very old drivers in the attribution of cause." However, in an earlier study (Hakamies-Blomqvist, as cited in Hakamies-Blomqvist, 1993), the judgements of responsibility were reviewed and it was found that doubt was cast over only one of 144 official judgements. Although a bias may exist, its effects are likely to be small.

A second objection to findings of an increased likelihood of responsibility for crashes among older drivers is that this apparent increase in at-fault drivers may represent, instead, a decreased involvement of older drivers in crashes when they are not at fault (Hakamies-Blomqvist, 1996, 2002; Keskinen et al., 1998). According to this point of view, both the responsible driver and innocent victim affect the probability of a collision. Older drivers, because of their slower, more cautious, conservative driving styles, are less likely to strike the vehicle of another driver who has made a mistake and put him or herself in a potentially hazardous situation. In this way, older drivers are less likely to strike another vehicle as the not-at-fault driver.

This theory has implications for the finding that older drivers are more likely to be responsible for intersection crashes (Hakamies-Blomqvist, 1993; Holland & Rabbitt, 1994; Hu et al., 2000; Preusser et al., 1998). Hakamies-Blomqvist (1998) noted that the chance of avoiding a crash as an innocent party is different for different crash types. For example, it is difficult to avoid innocent involvement in a high speed head-on crash but a cautious driving style could make it possible to avoid intersection crashes in which another driver is at fault. Therefore, the finding of older drivers being over-represented in crashes as the responsible driver, particularly for intersection crashes, is questionable.

The theory that older drivers are only over-represented as the responsible party in road crashes because they are less likely to be the innocent party in crashes also has implications for studies using induced exposure methods to investigate older driver crash involvement (e.g. Preusser et al., 1998; Robertson & Aultman-Hall, 2001; Stamatiadis & Deacon, 1997; Stamatiadis et al., 1990; Staplin & Lyles, 1991; Stutts & Martell, 1992). Such studies assume that drivers who are involved in crashes for which they are not responsible are a random sample of the driving population and, therefore, represent a good estimate of driving exposure for different groups of drivers. This method, according to the theory above, will under-estimate the driving exposure of older drivers and will, therefore, lead to over-estimates of older drivers' crash involvement per unit of driving exposure and over-estimates of their involvement as the responsible party in different crash types (Hakamies-Blomqvist, 1998).

One problem with this theory of the under-representation of older drivers in crashes as the not-at-fault driver is that, if this slower, more cautious driving style is a response to declining functional abilities (e.g. attention, vision, reaction time), then a cautious style and decrements in functioning could cancel each other out. This could produce a risk for non-responsible crash involvement that is equivalent to younger drivers, who may be functionally better but less cautious.

Older drivers, although often found to be over-involved in intersection crashes and more likely to be the responsible party, are less likely to be driving at excessive speed (Fildes, Rumbold, & Leening, 1991; Hakamies-Blomqvist, 2003; Maycock, 1997; OECD, 2001; Waller et al., 1977) or with an illegal blood alcohol concentration (Fildes, 1997; Hakamies-Blomqvist, 1994; Maycock, 1997; Mayhew, Donelson, Bierness, & Simpson, 1986; Mortimer & Fell, 1989; NHTSA, 2002; Sjogren et al., 1993) at the time of their crashes. Hakamies-Blomqvist (2003) and Eberhard (1996) both noted that these are strengths of the driving style of older drivers. Although older drivers appear to have difficulties with complex manoeuvres at intersections, they rarely exhibit any of the deliberate, unsafe actions implicated in the crashes of younger drivers (e.g. speeding, driving while intoxicated, dangerous overtaking). Taylor et al. (1994) explored traffic citations and crashes of drivers at different ages and concluded that, as drivers reach their sixties, they "go from being cited for speeding and being involved in single vehicle accidents to being cited for failure to yield the right of way and being involved in angle accidents" (pg 104). Daigneault et al. (2002b) viewed the difference between crash antecedents for young and old drivers in terms of Blockey and Havley's (1995) error and violation distinction. Errors are failures of planned actions to achieve a desired outcome, while violations are deliberate infringements of a code of behaviour, which in this case is the road rules. According to Daigneault et al. (2002b), older drivers tend to be involved in error crashes (e.g. turns at intersections), whereas younger drivers tend to be involved in violation crashes (e.g. single vehicle crashes caused by inappropriate speed). The mechanisms behind violation crashes are motivational in nature, while for error crashes, the failings are thought to be cognitive.

To summarise, older drivers have been found to be over-represented in crashes at intersections, especially non-signalised intersections. These intersection crashes are often preceded by turning movements, particularly turns across the path of oncoming traffic, and often involve failure on the part of the older driver to give way to other vehicles or to respond appropriately to a traffic sign or signal. Older drivers have also been found to be responsible for their crashes more often than drivers in younger age groups, although this finding has been questioned, largely because older drivers may be less likely to drive in such a way that drivers in other vehicles who make a mistake (e.g. a poorly executed turn) are hit following their errors. Older drivers have also been found to be less likely to drive in a deliberately unsafe manner, being less likely to drive at an excessive speed or after consuming alcohol.

1.3.10 Conditions in Which Crashes Occur

In addition to changes with age in crash characteristics, there are changes in the *conditions* in which crashes tend to occur. Specifically, older drivers have been found to be over-represented in daytime, rather than night time, crashes (Broughton, 1988; Campbell, 1966; Cerelli, 1989; Cooper, 1990b: Eberhard, 1996; Fildes, 1997; Fontaine & Gourlet, 1992; Hakamies-Blomqvist, 1994; Hauer, 1988; Massie et al., 1995; OECD, 2001; Preusser et al., 1998; Ryan et al., 1998; Stutts & Martell, 1992; Waller et al., 1977) and in crashes on weekdays rather than weekends (Stutts & Martell, 1992; Waller et al., 1977). However, they are under-represented in peak hour crashes (Cooper, 1990b; Eberhard, 1996; OECD, 2001) and in crashes occurring during inclement weather (Daigneault et al., 2002b; Eberhard, 1996; Fildes, 1997; Hakamies-Blomqvist, 1994; OECD, 2001). The explanation generally given for the specific conditions in which older drivers tend to crash has been that many older drivers are retired, enabling them to choose when they do their driving. Therefore, the drivers are able to choose not to drive in difficult conditions (Cooper, 1990b; Eberhard, 1996; Maycock, 1997).

Cooper (1990b) found that there are interactions between different driving conditions, with older Canadian drivers having fewer crashes during peak hour when the weather was inclement than at night during equivalent conditions. The first finding was thought to be because most retired drivers choose not to drive in peak hour in bad weather, while the second was attributed to the combined effects of low light and slippery roads, which may be too taxing for those older drivers who were willing to drive in such conditions (Cooper, 1990b). Hakamies-Blomqvist (1994), in a study of fatal crashes in Finland, attributed lower crash involvement in difficult conditions (e.g. night time) to avoidance of these conditions in order to compensate for declining ability. The finding that older drivers were less likely to be responsible for crashes in these conditions than younger drivers was attributed to further compensation, in the form of slower driving speed and less risk taking in older drivers. Stutts and Martell (1992) also attributed the declining crash involvement of older drivers in difficult conditions (e.g. night time) to compensatory behaviours. They added that due to the avoidance of difficult conditions by many older drivers, only those older drivers with higher levels of functioning chose to drive in difficult conditions, leading to no increase in crash involvement per kilometre driven for older drivers. The avoidance of difficult driving conditions and so-called "self-regulation" by older drivers is discussed in more depth in Chapter 4.

1.3.11 Summary of Patterns of Older Driver Crash Involvement

Older drivers have been found to have fewer crashes than their younger counterparts in absolute terms and also fewer crashes after adjustment for differences between age groups in terms of population numbers (e.g. OECD, 2001). However, a number of studies have found small increases in crash rates for the oldest drivers when the crash figures have been adjusted for differences between age groups in the number of licensed drivers (e.g. Ryan et al., 1998). Researchers have also been unanimous in finding that older drivers have higher crash rates per kilometre driven than all but the youngest drivers (those in their teens or early twenties) (e.g. Frith, 2002). The interpretation of these increased crash rates per kilometre driven, however, is complicated by older drivers' higher susceptibility to injury and, therefore, the increased likelihood that their crashes will be reported to the police and be included in official databases (e.g. Hakamies-Blomqvist, 2002). Another complication is the non-linear relationship between kilometres driven and crash risk per kilometre driven for drivers of all age groups. Those who drive more kilometres per year have lower crash rates per kilometre driven, regardless of age. It has been argued on the basis of this that older drivers have higher crash rates per kilometre driven than drivers in other age groups because they tend to drive less (e.g. Hakamies-Blomqvist, 2003). Although it is difficult to determine the extent to which decreased driving ability, susceptibility to injury, and the "low mileage bias" contribute to the increased crash risk per kilometre driven of older drivers, it is clear that older drivers are at risk of injurious crashes to a greater extent than those in younger age groups. Moreover, predictions for the future suggest that the number of crashes of older drivers is likely to increase substantially in the coming years due to the aging population, increased rates of older driver licensure, and increased older driver mileage (e.g. Federal Office of Road Safety, 1996).

There are also differences in the characteristics of the crashes of older drivers and in the conditions in which they occur, compared to the crashes of drivers in other age groups. Specifically, older driver crashes are more likely to produce serious injuries (e.g. Lyman et al., 2002) and are more likely to occur at intersections, especially non-signalised intersections (e.g. Hu et al., 2000). These intersection crashes have been associated with older drivers' failure to give way, failure to obey traffic signs or signals, and turning manoeuvres, especially turns across traffic (e.g. Preusser et al., 1998). Older drivers have also been identified as a group of drivers who are more likely to be found responsible for their crashes (e.g. Maycock, 1997), although this finding has been questioned by some (e.g. Hakamies-Blomqvist, 1996). It has also been found that older drivers rarely have crashes involving excessive speed (e.g. Fildes et al., 1991) or alcohol intoxication (e.g. NHTSA, 2002). Moreover, older driver crashes rarely occur at night, on weekends, in peak hour traffic, or in inclement weather (e.g. OECD, 2001).

As this thesis is concerned with the driving behaviour of older drivers, and is based on a sample of drivers in South Australia, the crash patterns of South Australian older drivers were examined to see whether they conform with the results reported in other jurisdictions. To this end, the following chapter presents an analysis of police-reported crash involvement by age group, over a period of five years in South Australia. Crash rates are presented per head of population, per licensed driver, per kilometre driven, and in terms of different crash characteristics and conditions in which crashes occur.

CHAPTER 2: OLDER DRIVER CRASH INVOLVEMENT IN SOUTH AUSTRALIA

2.1 Introduction

This chapter presents an analysis of the crash involvement patterns of drivers in South Australia, according to age group. In particular, it focuses on older drivers (those aged 65 years or more) and is an attempt to verify previously reported crash involvement patterns for drivers in this age group.

As described in Chapter 1, numerous relationships between aging and crash involvement have been reported in the literature. These relationships have concerned the number of crashes in which drivers of older age groups are involved, the characteristics of the crashes in which they tend to be involved, and the conditions in which these crashes tend to occur.

With respect to the number of crashes, it is reported that older drivers tend to have lower crash rates than younger drivers (those aged under 65). This is the case even after adjusting rates of crash involvement for differences between age groups in population and extent of driving licensure, although there are small increases in crash rates per licensed driver among the oldest age groups (those aged over 75) (e.g. OECD, 2001). It is only when the crash rates for different age groups are expressed in terms of crashes per kilometres driven that older drivers (those aged over 65) are found to have higher rates of crash involvement than younger drivers (e.g. Ryan et al., 1998).

In addition, changes with age are reported for the characteristics of the crashes in which drivers tend to be involved. Crashes involving older drivers have been found to produce greater levels of injury severity, on average, than those involving younger drivers, with older drivers more likely to be involved in collisions causing serious injury or a fatality (e.g. Lyman et al., 2002). Crashes involving older drivers are more likely to occur at intersections and to involve more than one vehicle (e.g. Hakamies-Blomqvist, 1993). This increased likelihood of intersection crashes has been associated with difficulties in executing turn manoeuvres at intersections, particularly turn manoeuvres across the path of oncoming traffic to which the driver of the turning vehicle must yield right of way (e.g. Preusser et al., 1998). Failure to yield right of way and failure to observe traffic signals or signs (usually Stop or Give Way signs) are common errors exhibited by older drivers (e.g. Eberhard, 1996). Moreover, drivers in older age groups are more likely to be deemed to be responsible for the crashes in which they are involved (e.g. Cooper, 1990a). Older drivers, however, are less likely to have been driving at an excessive speed at the time of the crash (OECD, 2001) or to have been driving with an illegal blood alcohol concentration (BAC) than are younger drivers (e.g. Hakamies-Blomqvist, 1994).

Older drivers also exhibit different crash patterns to their younger counterparts in terms of the conditions in which the crashes occur. Crashes involving older drivers, for example, are less likely to occur during peak hour traffic (e.g. Eberhard, 1996). They are also less likely to occur in inclement weather (e.g. OECD, 2001) or during hours of darkness (e.g. Ryan et al., 1998).

This study sought to assess whether the crash patterns of older drivers in South Australia resembled those routinely reported in the literature. More specifically, it examined the crash experience of older drivers in terms of their frequency and rate of crashes (total number, number per head of population, number per licensed driver and number per kilometre driven), crash characteristics (crash injury severity, driver injury severity, intersection involvement, crash type, vehicle movement prior to the crash, apparent driver error, driver responsibility, involvement of excessive speed, alcohol involvement) and the conditions in which crashes occur (time of day, ambient illumination, weather conditions, wetness of the road).

This analysis was undertaken to check that the population of drivers (South Australian older drivers) from which a sample was drawn for a subsequent study on older drivers' driving behaviour was typical of older driver populations in general. If the South Australian older driver population exhibited crash patterns comparable to other older driver populations reported in the literature, then the results of the subsequent study on driving behaviour would be more likely to be generalisable to older drivers elsewhere. South Australia is a state of Australia with a population of approximately 1.5 million inhabitants, with around three quarters of the population concentrated in the statistical division of the capital city, Adelaide. The mean driving-age population (16 years of age or over) was approximately 1.15 million for the years covered by this study of crash involvement (1994 to 1998).

In order to assess the crash patterns of older drivers, the Traffic Accident Reporting System (TARS) database maintained by the South Australian Department of Transport (Transport SA) was used to obtain crash data for a period of five years. All relevant variables were analysed in terms of the age group of the crash-involved drivers.

On the basis of the literature review presented in Chapter 1 and summarised above, it was hypothesised that there would be a number of differences between the crash patterns of older and younger drivers. The hypotheses, with regard to the number of crashes, the characteristics of the crashes and the conditions in which crashes occur, were as follows:

2.1.1 Number of Crashes

- Older drivers (those aged over 64) would be involved in *fewer* crashes than younger drivers (aged 16-64).

- Older drivers would be involved in *fewer* crashes per head of population than younger drivers.
- Older drivers would be involved in *fewer* crashes per licensed driver than younger drivers.
- Older drivers would be involved in *more* crashes per kilometre driven than younger drivers.

2.1.2 Crash Characteristics

- Crashes involving older drivers would be *more* likely to have resulted in a fatality or serious injury compared with crashes involving younger drivers.
- Older drivers involved in a crash would be *more* likely to have been seriously injured or killed than younger drivers.
- Crashes involving older drivers would be *more* likely to have occurred at intersections than those involving younger drivers.
- Crashes involving older drivers would be *more* likely to have been right turn collisions than those involving younger drivers.
- Older drivers would be *more* likely to have been turning prior to the crash than younger drivers.
- Older drivers would be *more* likely to have been the driver turning right in right turn crashes than younger drivers.
- Older drivers would be *more* likely to have failed to obey a traffic signal or to have failed to give way, particularly at Stop or Give Way signs, than younger drivers.
- Older drivers would be *more* likely to have been deemed by the investigating officer to be responsible for the crash they were involved in than younger drivers.

- Older drivers would be *less* likely to have been driving at an excessive speed than younger drivers at the time of the crash.
- Older drivers would be *less* likely to have recorded an illegal blood alcohol concentration than younger crash-involved drivers.

2.1.3 Conditions in Which Crashes Occur

- Older drivers would be *less* likely to have been involved in a crash during peak traffic times than younger drivers.
- Older drivers would be *more* likely to have been involved in a crash in daylight conditions than younger drivers.
- Older drivers would be *less* likely than younger drivers to have been involved in a crash when the roads in the vicinity were wet.
- Older drivers would be *less* likely than younger drivers to have been involved in a crash when it was raining.

2.2 Method

2.2.1 Crash Data

The study was based on an analysis of data recorded in the Traffic Accident Reporting System (TARS) database maintained by the Traffic Information Management Section of Transport SA. The TARS database is a record of all road crashes in South Australia that are reported to the police. Crash participants are required to report their crash to the police if the crash results in a person being injured or if it causes property damage in excess of $1,000 (Australian dollars). Prior to January 1, 1998, crashes in which property damage exceeded $600 in non-injury crashes were required to be reported to the police. The details of all crashes in South Australia matching these criteria are entered into the TARS database.

The variables contained within the database refer to a number of characteristics of the crash, including those of the drivers (e.g. age, sex, blood alcohol concentration), the vehicles (e.g. type, year of manufacture), the roads (e.g. speed limit, road surface), the nature of the crash itself (e.g. vehicle movement, crash type), the environment (e.g. lighting conditions, weather conditions), and the outcome of the crash (e.g. injury severity, damage estimate). A complete list of the variables contained within the database is provided in Appendix 2A.

Crash data for the years 1994 to 1998 inclusive were chosen for this analysis. The year 1998 was chosen because it was the most recent year for which the database was complete when this study was conducted, whilst 1994 was chosen as the first year because a period of five years was thought to provide an adequate time frame in which to obtain a representative sample of crash data.

In order to analyse the crash data in terms of the age group of drivers involved in the crashes, it was necessary, because of the structure of the TARS database, to base the analysis on crash-involved drivers rather than crashes. This means that for crashes in which there was more than one driver/vehicle, the details of the crash would be represented more than once in the data extracted from TARS for analysis. Crash-involved drivers were chosen for inclusion in the analysis only if they were driving a car or car derivative (station wagon, panel van, utility). This was done to exclude data for different subgroups of drivers (e.g. motorcyclists, truck drivers) whose characteristics may differ systematically from other motorists in ways that might have affected the results if included. Motorcycle riders involved in crashes, for example, are disproportionately young males (Holubowycz, Kloeden, & McLean, 1994).

The age groups for whom the crash data were analysed were: under 16, 16-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85 and over, and age unknown. Drivers under the age of 35 were classified for the purpose of this report as “young” drivers, those aged from 35 to 54 as "middle-aged" drivers, those aged from 55 to 64 as "young-old" drivers, and those aged over 64 as "older" drivers.

Although South Australia does not permit the licensure of those under 16, there were a number of crashes involving drivers under the age of 16. Other than the preliminary statistics for crash numbers, drivers under the age of 16 were excluded from subsequent analyses because these drivers represent a subgroup of those aged under 16 who, by the very act of driving when the crash occurred, were breaking the law, and who had not officially demonstrated the minimum skill level and knowledge necessary for a licence.

2.2.2 Population Data

Estimates of the South Australian population for the different age groups in June of each year from 1994 to 1998 were obtained from Australian Bureau of Statistics (ABS) publications (Australian Bureau of Statistics, 1997, 1998, 1999). These data were used to determine an estimate of the average annual population over the five years for each age group. This average population was used to calculate the crash rate per head of population for each age group.

2.2.3 Driver Licensing Data

Driver licensing data were obtained from Registration and Licensing, a section of Transport SA. Requests were made to Registration and Licensing for the number of licensed drivers in South Australia, broken down by age group, for each year from 1994 to 1998 inclusive. These data, however, were only available for December 1999. Although determining crash rates per licensed driver using licensing data from a year after the end of the time period being studied is not ideal, it is assumed that any biases introduced by the use of the 1999 data would be small and would not have a meaningful effect on the results of comparisons across age groups. Given the increasing number of older licensed drivers (refer to Chapter 1), it is possible that the proportion of older licensed drivers in 1999 is greater than the average across the years from 1994 to 1998. If this is the case, then the results would provide a conservative estimate of any increases with age in crash rates per licensed driver.

In South Australia, a person must be 16 years old before they can apply for a learner driver permit. Learner drivers must be accompanied when driving by a fully licensed driver, must have a zero blood alcohol concentration and must drive no faster than 80 km/h. Upon reaching the age of 16 years and 6 months, a learner driver may apply for a provisional licence. A provisional licence is granted if the driver passes an on-road driving test or has undergone extensive on-road training with a qualified driving instructor. With a provisional licence, a driver must have a zero blood alcohol concentration and must drive no faster than 100 km/h (the maximum speed limit on specific roads in South Australia is 110 km/h). A provisional licence lasts until the age of 19 or for a year if the licence is obtained when the driver is aged 18 or over. The driver is then eligible for a full licence. Drivers aged over 70 are required to get an annual medical check-up to maintain their licence.

2.2.4 Driver Exposure Data

Driving exposure data, in terms of kilometres driven by South Australian drivers, were obtained from the Australian Bureau of Statistics. The data were derived, on request, from the Australian Bureau of Statistics' Survey of Motor Vehicle Use (Cat No 9208.0) for the 12 months ending 31st June, 1998. The Surveys of Motor Vehicle Use are designed to collect information regarding the amount of driving done in different types of vehicle, rather than by different types of driver. That is, they are vehicle-based rather than driver-based surveys. The surveys report on a sample of vehicles and report the number of kilometres driven in the vehicles. The only information about drivers that is sought is the age and gender of those who drive a sampled vehicle and the proportion of the total distance travelled by the vehicle for which each driver is responsible. Therefore, the Australian Bureau of Statistics data refer to the average number of kilometres driven by drivers in a particular sampled vehicle. The data do not take into account the possibility that some drivers may drive multiple vehicles and may, therefore, underestimate the number of kilometres driven by some of the drivers in the sample. For the purposes of this chapter, in which only relative comparisons across different age groups are of importance, rather than absolute figures, it is assumed that drivers in different age groups do not systematically differ from each other in terms of the extent to which they spread their driving between different vehicles.

The information requested from the Australian Bureau of Statistics was for passenger vehicles only. This subset of vehicles includes cars, station wagons, hatchbacks, passenger vans or minibuses with fewer than ten seats, four wheel drive vehicles with fewer than ten seats, and campervans. Taxis, motor cycles, trucks and buses were excluded. This subset of vehicles matches closely those chosen from the TARS database for inclusion in the analysis.

2.2.5 Analyses

The number of crashes involving drivers of different age groups was determined first, before crash rates for different age groups were calculated in terms of a number of different measures of exposure: crashes per head of population, crashes per licensed driver and crashes per kilometre driven. To investigate crash characteristics and the conditions in which crashes occur, the crashes were then analysed in terms of a number of variables within the TARS database that were indicated by the literature as showing a relationship with aging. The variables chosen were: crash injury severity, driver injury severity, intersection type, crash type, vehicle movement prior to the crash, type of apparent driver error, responsibility of the driver for the crash, blood alcohol concentration of the driver, hour of the day when the crash happened, ambient lighting conditions, wetness of the road, and the presence of rain. Each of these variables was analysed in terms of the age of the crash-involved drivers.

Due to the very large size of the crash sample used in this study, the normal method of analysing frequency data, χ^2 analyses, was likely to detect statistically significant differences where inspection of the data would suggest that differences were minimal and of no practical interest. Therefore, instead of using χ^2 analyses, data points for crash characteristics were expressed, where possible, in terms of 99 per cent confidence intervals, and statistical significance at the $p < .01$ level was determined by inspection of the presence or absence of crossover of confidence intervals. That is, two or more values were deemed to differ significantly ($p < .01$) if there was no overlap between the confidence intervals of the groups being compared. This method of determining statistical significance had the advantage of allowing for multiple pairwise comparisons between different age groups. Confidence intervals were calculated for all variables related to crash characteristics and the conditions in which crashes occur by treating these variables as binomial distributions (e.g. was in a right turn crash or was not in a right turn crash; crashed in the rain or did not crash in the rain). As crash rates could not be treated in the same manner, confidence intervals were not calculated for them.

The conservative alpha level of .01 was chosen to correct for multiple comparisons. A conservative alpha level was used rather than using the Bonferroni method of correcting for multiple comparisons because it has been argued that the Bonferroni method is too conservative when the number of comparisons is large (Jaccard & Wan, 1996).

2.3 Results

2.3.1 Number of Crashes

To determine the extent of crashes in South Australia involving older drivers, the following section provides details of the number of crashes recorded in the TARS database for the specified age groups in the years from 1994 to 1998. This is followed by details of the crash rates for these age groups in terms of the number of persons in the population (section 2.3.1.2), the number of licensed drivers (2.3.1.3), and the average number of kilometres driven per year (2.3.1.4).

2.3.1.1 Driver Age

In the years 1994 to 1998 in South Australia, there were 331,590 drivers of passenger vehicles (as described above) who were involved in crashes reported to the police[1]. The age of the driver was known to the police in 260,361 (78.5%) cases. The number of drivers in each age group is shown in Table 2.1, which reveals that with increasing age (excluding those under the age of 16, who were not licensed drivers), there was a decrease in the number of drivers involved in crashes. These data therefore support the hypothesis that older drivers would be involved in fewer crashes than younger drivers.

2.3.1.2 Crashes per Head of Population

The mean estimated population for each of the specified age groups in South Australia from 1994 to 1998 is provided in Table 2.2. As can be seen, there were substantial differences in the populations of the age groups. The population decreased with increasing age over 44, with 7.5 per cent of people aged over 74 and less than two per cent aged over 84.

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[1] Drivers involved in multiple crashes were counted separately for each crash. Therefore, the number of *different* drivers involved in crashes in South Australia in 1994 to 1998 would be less than 331,590. For the purposes of this chapter, the number of crash-involved drivers in an age group refers to the number of instances of crash involvement for drivers in the age group.

Table 2.1

Age of crash-involved drivers in South Australia, 1994 to 1998

Age Group	Number of Crashes	Percent of known
<16	209	0.1
16-24	73,645	28.3
25-34	58,062	22.3
35-44	49,600	19.1
45-54	35,658	13.7
55-64	19,833	7.6
65-74	15,142	5.8
75-84	7,275	2.8
85+	937	0.4
Unknown	71,229	-
Total known	260,361	100.0
Total	331,590	

Table 2.2

Mean estimated population in South Australia, 1994-1998, by age group

Age Group	Age Group Total	% of Total
16-24	185,025	16.0
25-34	221,681	19.2
35-44	225,051	19.5
45-54	188,220	16.3
55-64	130,701	11.3
65-74	118,853	10.3
75-84	67,661	5.8
85+	19,537	1.7
Total	1,156,729	100.0

As some age groups comprised a greater share of the population, these age groups would be expected to have comprised a greater share of the population of crash-involved drivers. Therefore, to gain a better indication of the likelihood of drivers in different age groups being involved in crashes, crash rates were adjusted according to these population differences (i.e. number of crashes divided by population, calculated for each age group). The percentages of the population in each age group who were involved in a crash between 1994 and 1998 are presented in Figure 2.1 (data are provided in Appendix 2B, Table 1). As noted earlier, for the purposes of this study, two crashes involving the same driver were counted as two separate crash-involved drivers. This would have resulted in an overestimate of the percentage of the population who had experienced a crash in the study period.

The rates of crash involvement adjusted for population again show that younger drivers were over-represented in crashes compared with middle-aged and older drivers.

The lowest rates of crash involvement were for the oldest age groups. This is consistent with the hypothesis that older drivers have lower crash rates than younger drivers after adjusting crash rates for differences in population between different age groups. This association between aging and decreased crash involvement does not appear to be as strong, however, as when population differences across groups are not taken into account (see section 2.3.1.1).

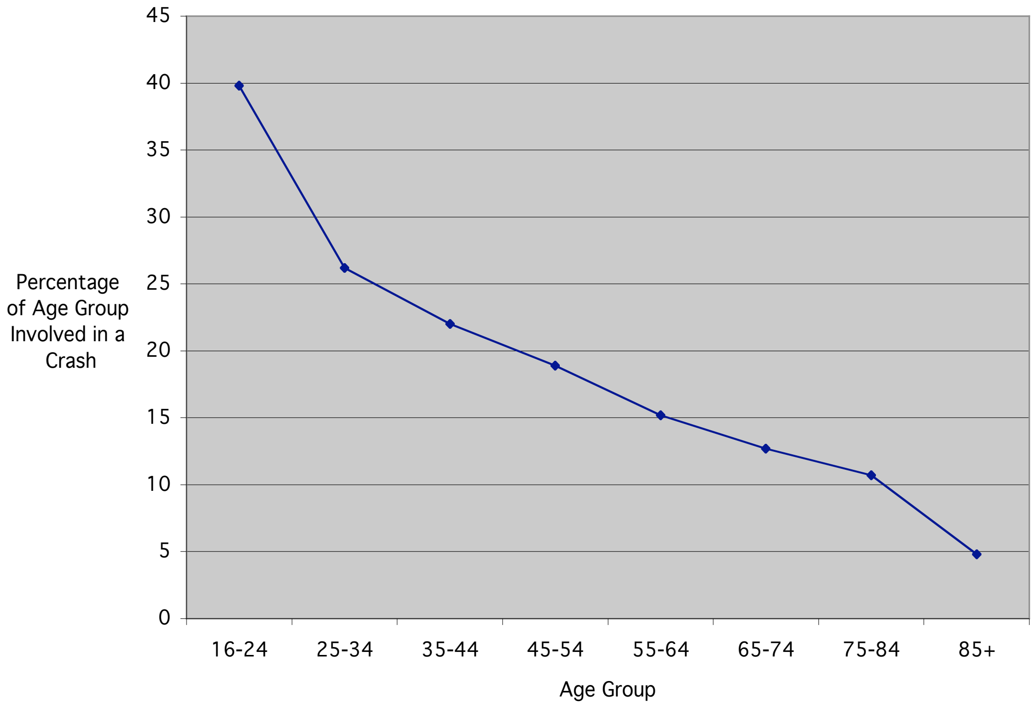

Figure 2.1. Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group

When the data represented in Figure 2.1 are adjusted for different levels of crash injury severity (defined as the injury level of the most severely injured person in the crash), it becomes apparent that the crash involvement rates per head of population of younger drivers were greater particularly for the lower levels of severity. This can be seen in Figure 2.2, which provides the ratio between the crash involvement rates of each age group and that of the group with the lowest level of crash involvement per head of population (the over 85 age group), for each of five levels of crash injury severity (property damage only, private doctor treated, hospital treated, hospital admission, and fatal). The highest ratios were for crashes requiring treatment from a private doctor and those only resulting in property damage, while the lowest ratios were for crashes resulting in hospital admission or fatalities. For fatalities, only those aged 16 to 24 or 25 to 34 had higher involvement rates than those aged 75 to 84, and the age group with the lowest involvement rate was the 45 to 54 group. (A table of the ratios represented in Figure 2.2 is provided in Appendix 2B, Table 2.)

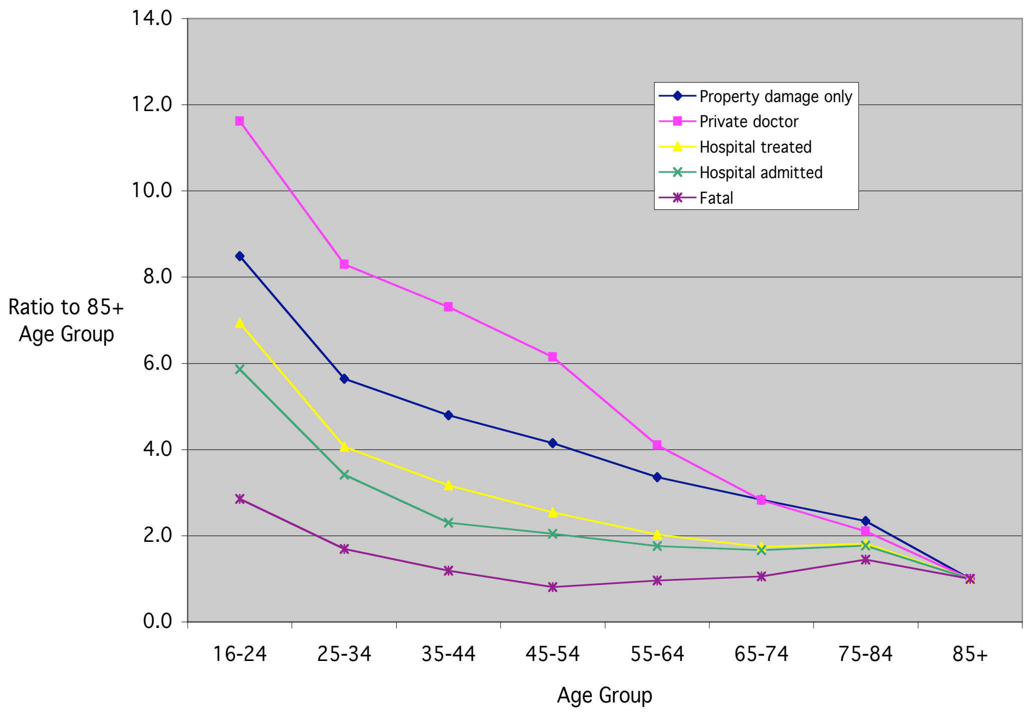

Figure 2.2. Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged Over 84

These differences in age-related crash involvement rates per head of population are consistent with the hypothesis that older drivers would be more likely to be involved in crashes resulting in a fatality or severe injury. One unexpected result shown in Figure 2.2 is that the highest ratios between younger drivers and the 85+ age group for crash involvement per head of population were for crashes resulting in injuries requiring treatment from a private doctor (rather than for property damage only crashes). This suggests that older drivers are under-represented in this crash injury severity category. One possible explanation for this is that when older vehicle occupants are injured in a crash, they are more likely to be taken to a hospital for treatment as a precautionary measure. When young or middle-aged occupants have minor injuries, they are more likely to be advised that seeing a private doctor for treatment would be adequate.

2.3.1.3 Crashes per Licensed Driver

The number of licensed drivers in 1999 in each age group is provided in Table 2.3. As can be seen, there was a decrease in the number of licences held in South Australia with increasing age, after a peak in the group aged 25 to 34. The smallest number of licensed drivers was for those in the over 84 age group. It also needs to be noted that the proportion of total licence holders over 65 (13.9%) was less than the proportion of older persons in the population (17.8%), indicating that older people were less likely to hold a driver's licence than the rest of the driving-age population.

Table 2.3

Number of licensed drivers in South Australia, 1999, by age group

Age Group	Age Group Total	% of Total
16-24	129,162	15.4
25-34	178,027	21.2
35-44	175,167	20.9
45-54	147,437	17.6
55-64	92,418	11.0
65-74	72,582	8.7
75-84	38,880	4.6
85+	4,781	0.6
Total	838,454	100.0

These differences across age groups in licensure rates need to be taken into account when calculating driver crash rates for the different groups. Figure 2.3 displays the crash rates in the five year period 1994 to 1998 per licensed driver for each age group (refer to Appendix 2B, Table 3 for data). The rates of crash involvement per licensed driver follow a similar pattern to the rates expressed in terms of crashes per head of population (refer to Figure 2.1). Again, older drivers had lower crash rates than drivers in younger age groups, with drivers aged 75 to 84 having the lowest rates of all. The hypothesis that older drivers would still have lower crash rates than younger drivers when differences in licensing rates were taken into account is therefore supported by these data.

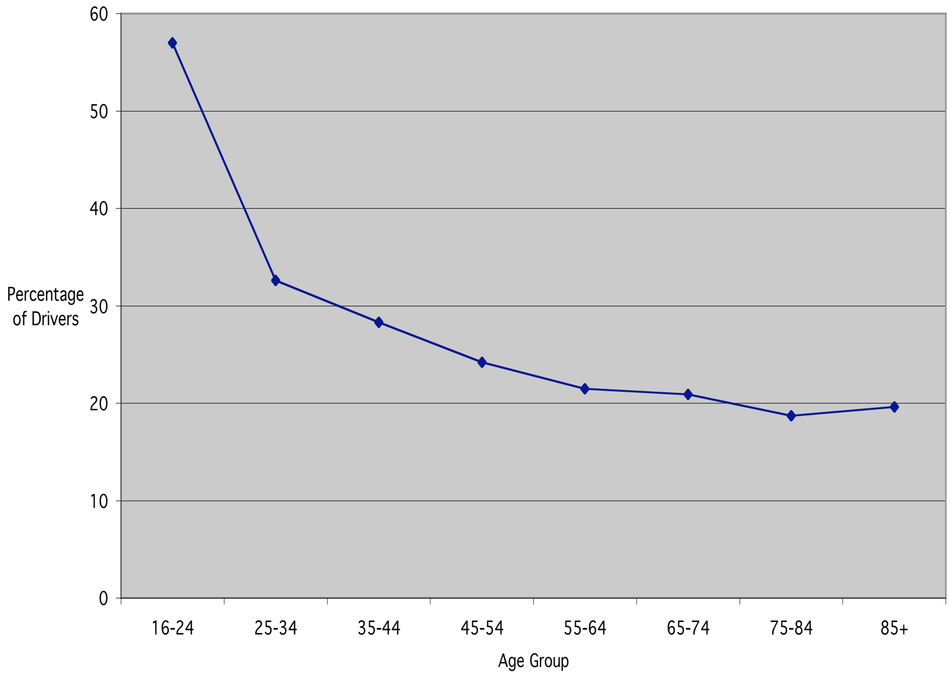

Figure 2.3. Percentage of Licensed Drivers Involved in Crashes in South Australia from 1994 to 1998, by Age Group

Crashes per licensed driver should also be broken down according to crash injury severity. Figure 2.4 provides the ratio of crash-involved drivers in each age group to the number of crash-involved drivers in the 75 to 84 age group (the group with the lowest level of crash involvement) for each level of crash injury severity (refer to Appendix 2B, Table 4 for data). Figure 2.4 shows that the rate of fatal crashes was lowest for middle-aged drivers (aged 45 to 54) and that the fatal crash rate for drivers aged over 84 matched that of drivers in the youngest age group. For crashes resulting in hospital admission, the lowest rate was for drivers aged 55 to 64, with small increases in the crash rate for drivers aged over 64. This provides support for the hypothesis that older drivers would be more likely to be involved in crashes of high injury severity.

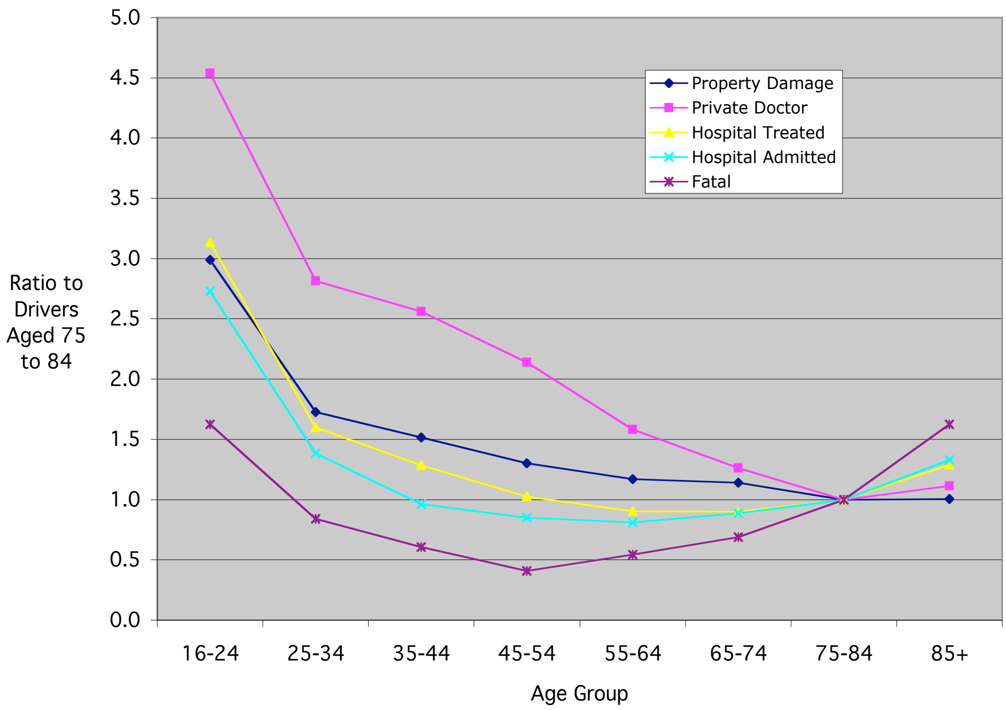

Figure 2.4. Crash-Involved Drivers per Licensed Driver in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 75 to 84

2.3.1.4 Crashes per Kilometres Driven

The number of kilometres driven by the average driver in each age group in the 12 months to July 1998 is shown in Figure 2.5 (refer to Appendix 2B, Table 5 for data). It can be seen that a reduction in driving occurred for those aged over 74. The group of drivers aged between 65 and 74 drove approximately the same number of kilometres per year as middle and late middle-aged drivers (aged 35 to 64), but those aged in the 75 to 84 year old group drove only half as much as drivers in these age groups, while the average number of kilometres driven per year by those aged over 84 was reported by the Australian Bureau of Statistics to be zero. This clearly understates the annual driving done by those in this age group and must merely be taken as an indication that the amount of driving done is very low.

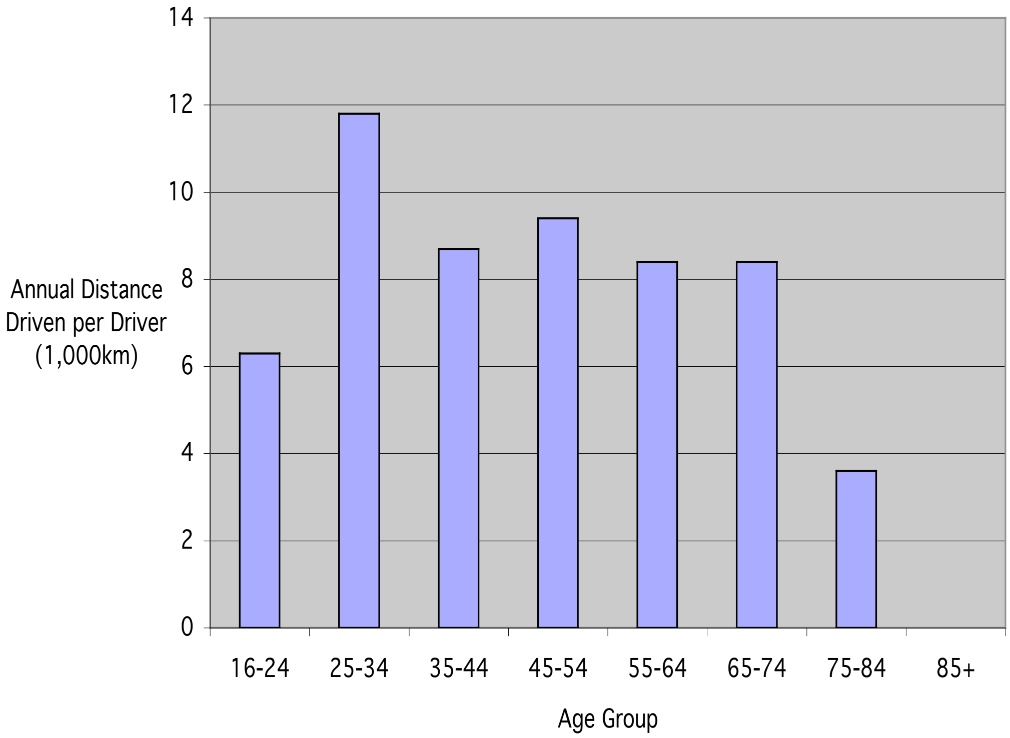

Figure 2.5. Average Kilometres Driven (x 1,000) by Drivers in South Australia in the 12 Months 1997-1998, by Age Group

These differences in the amount of driving done by drivers across the age groups need to be considered when calculating crash rates for these groups. In order to calculate crash rates per distance driven, the total number of crashes for each age group occurring in the years 1994 to 1998 (refer to Table 2.1) were divided by five to derive a yearly crash average. This number was then divided by the total number of kilometres driven per year by the drivers in each age group (the average number of kilometres driven as shown in Figure 2.5, multiplied by the number of licensed drivers in each group as shown in Table 2.3) in the 12 months to July 1998. As the resulting crash numbers are small, the crash rate is best expressed as crashes per million kilometres driven. The results are shown in Figure 2.6 (refer to Appendix 2B, Table 6 for data). The crash rates for drivers aged over 84 are not shown because, as noted earlier and shown in Figure 2.5, the average number of kilometres driven each year by drivers in this age group was reported by the Australian Bureau of Statistics to be zero.

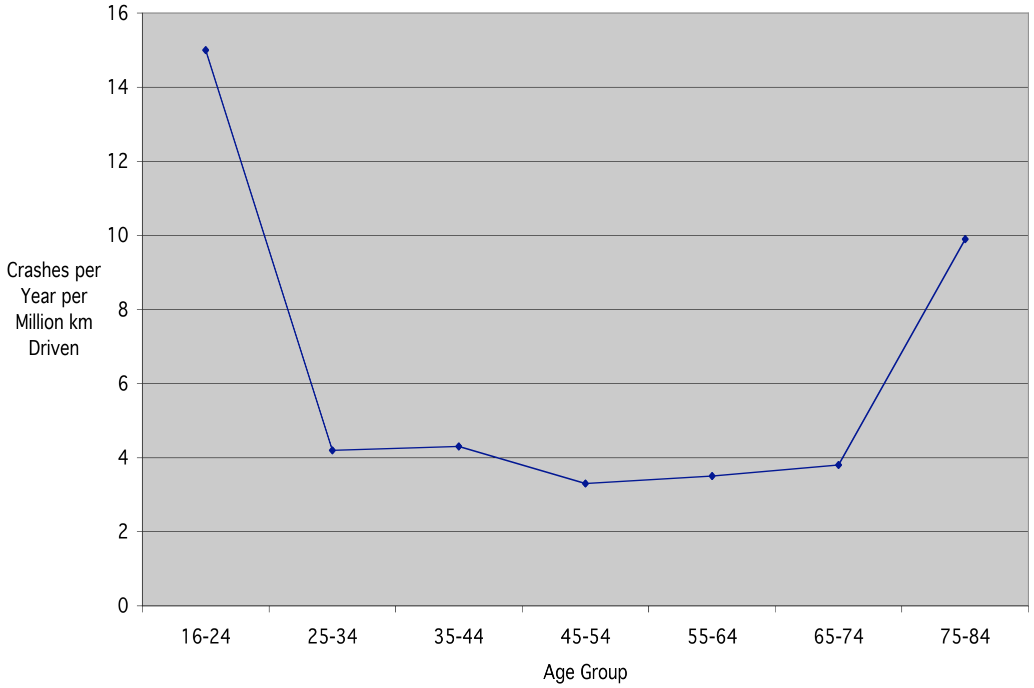

Figure 2.6. Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group

As can be seen in Figure 2.6, young drivers aged under 25 had the highest crash rate per distance driven. The second highest crash rate was that of older drivers, aged over 74. All other groups of drivers, aged between 25 and 74, had crash rates that were approximately equivalent. Drivers aged over 84 are likely to have had a higher crash rate per kilometre driven than the young drivers, given the very low amount of driving done by this group, but this rate was unable to be computed. Nonetheless, the data provide partial support for the hypothesis that a detrimental effect of aging on the risk of crash involvement would be most apparent when crash rates were expressed in terms of crashes per kilometre driven.

Crashes per kilometre driven also need to be analysed in terms of crash injury severity. Figure 2.7 shows the ratio of the number of crash-involved drivers per kilometre driven in each age group relative to that in the age group 45 to 54 (the group with the lowest crash involvement rate per kilometre driven) for each level of crash injury severity (see Appendix 2B, Table 7 for data). It can be seen in Figure 2.7 that the ratios of crash involvement rates were highest for fatal crashes among older drivers aged over 74 and younger drivers aged under 25. The fatal crash rates of drivers aged from 65 to 74 and from 25 to 34 were also approximately double those among drivers aged 45 to 54. This means that, per kilometre driven, both young and older drivers were more likely than middle-aged drivers to be involved in fatal crashes. This is consistent with the hypothesis that older drivers are over-involved in high injury severity crashes. It can also be seen that drivers over 74, compared to middle-aged drivers, were not only more likely to be in fatal crashes but also had higher rates of crashes either resulting in less severe injuries or not resulting in injury (property damage only). The lowest relative rates of crash involvement per kilometre driven for older drivers were for crashes resulting in injuries treated by a private doctor. As noted earlier, this is likely to be because older vehicle occupants who are injured are more likely to be taken to hospital as a precautionary measure.

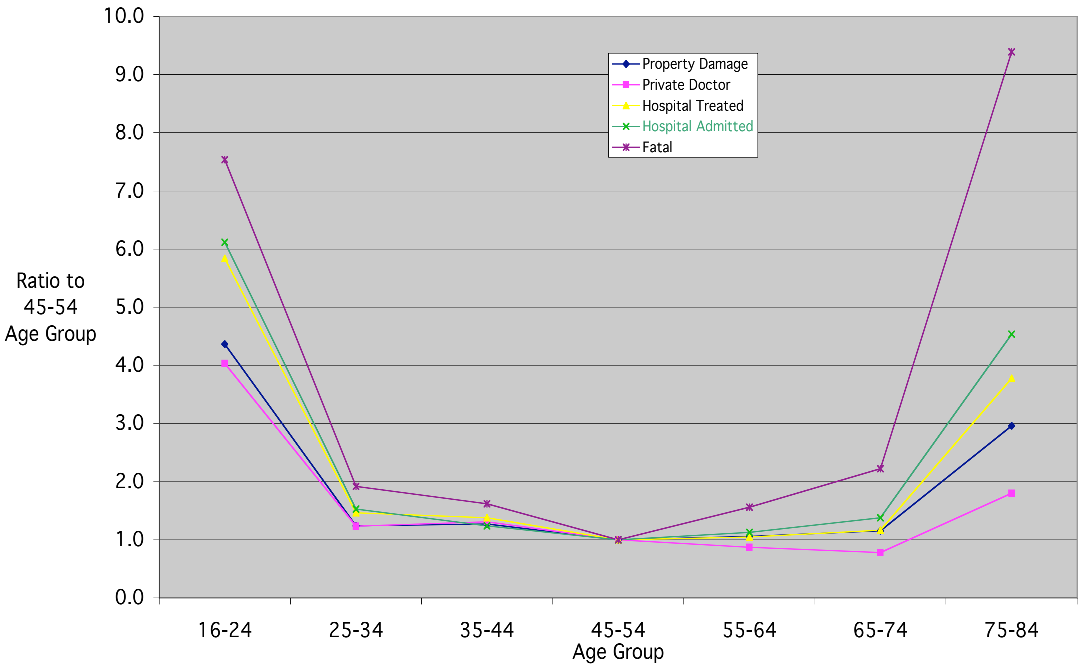

Figure 2.7. Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 45 to 54

2.3.1.5 Number of Crashes: Summary

The preceding sections have shown that older drivers (aged over 64) were involved in relatively few crashes compared with younger drivers (aged under 65), and also had lower crash rates than younger drivers after adjusting for differences between the specified age groups in terms of population, and the number of licence holders. After adjusting for differences in the amount of driving done by each of the age groups, it was found that crash rates were reasonably constant for those aged between 25 and 74. Higher crash rates were found only for those drivers under the age of 25 and over the age of 74. When the various crash rates (crashes per head of population, per licensed driver, per kilometre driven) were analysed in terms of crash injury severity, it was found that older drivers were over-represented in crashes resulting in fatal injuries. These results were all consistent with the hypotheses.

2.3.2 Crash Characteristics

The following sections explore differences in the characteristics of the crashes involving drivers of different age groups. The variables analysed were crash injury severity (section 2.3.2.1), driver injury severity (2.3.2.2), intersection type (2.3.2.3), crash type (2.3.2.4), vehicle movement prior to the crash (2.3.2.5), driver error (2.3.2.6), driver responsibility for the crash (2.3.2.7), excessive speed (2.3.2.8), and driver blood alcohol concentration (2.3.2.9).

2.3.2.1 Crash Injury Severity

In the TARS database, crash severity is defined in terms of the level of injury sustained by the most severely injured crash participant (vehicle occupant or other road user). As noted previously, there are five different levels of severity used in the database: property damage only (no injury), injury requiring treatment from a private doctor, injury requiring treatment at a hospital, injury requiring admission to a hospital, and fatal injury. The percentage of crashes in which a person (vehicle occupant or pedestrian) was seriously injured (admitted to hospital or killed) for each age group is represented in Figure 2.8 (refer to Appendix 2B, Table 8 for data and associated 99 per cent confidence intervals).

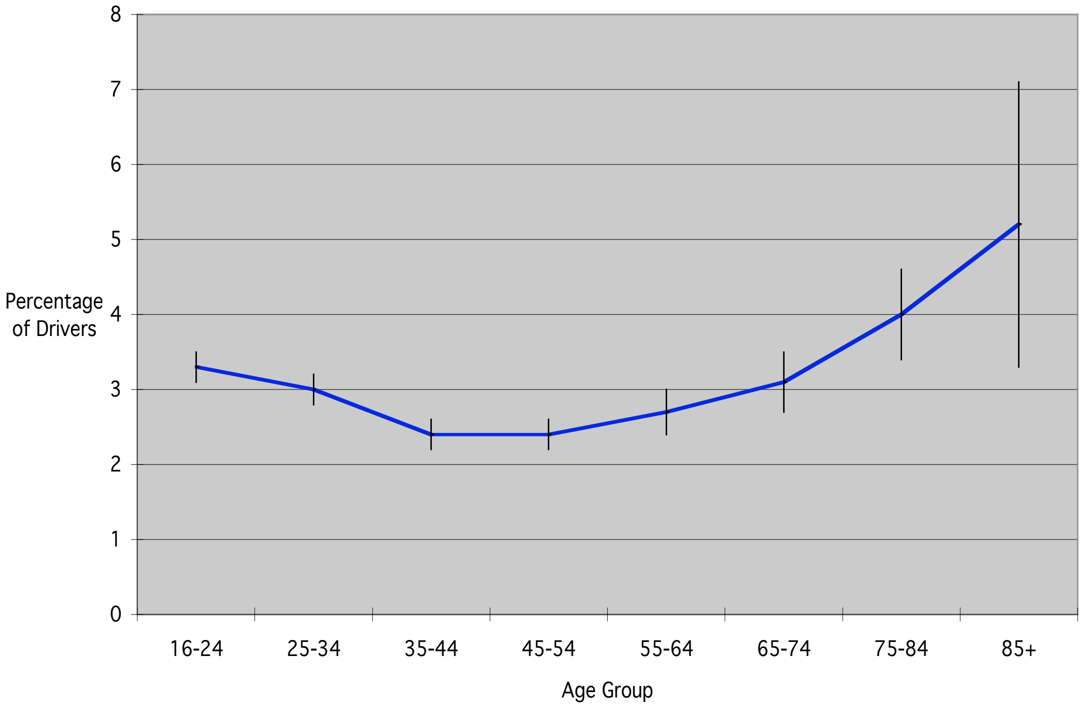

Figure 2.8. Crash-Involved Drivers Whose Crashes Resulted in a Serious or Fatal Injury to One or More Crash Participants in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Figure 2.8 illustrates that middle-aged drivers (35 to 54) were the least likely to be involved in crashes in which someone was seriously or fatally injured, whilst the highest likelihood of this occurring was for those crashes involving drivers aged over 74, reaching a peak of 5.2 per cent of crashes for those involving a driver aged over 84. Those drivers over the age of 64 were significantly more likely to be involved in a severe crash than those aged 35 to 54, while those aged over 74 were significantly more likely to be involved in a severe crash than those aged 25 to 64. The increased likelihood of older drivers being involved in crashes resulting in injury is consistent with expectations. This is also consistent with analyses of crash rates presented in sections 2.3.1.2, 2.3.1.3 and 2.3.1.4.

Crashes in which the age of one or more of the drivers was unknown were rarely severe (0.6%). The likely reason for this is that the crashes in which police were not able to obtain ages of drivers would have included a high proportion of crashes in which one of the drivers in question had left the scene of the crash before the arrival of the police, and a high proportion of cases in which the crash had been reported later at a police station. These scenarios would be less likely to occur in serious injury crashes.

2.3.2.2 Driver Injury Severity

The severity of injury sustained by the drivers has also been recorded using the same categories as those used for overall crash injury severity: no injury, injury requiring treatment from a private doctor, injury requiring treatment at a hospital, injury requiring admission to a hospital, and fatal injury. The percentage of crash-involved drivers in each age group who suffered a serious or fatal injury (admitted to hospital or killed) is depicted in Figure 2.9 (refer to Appendix 2B, Table 9 for data and 99 per cent confidence intervals).

The data for driver injury generally mirror those for overall crash injury severity, with a lower incidence of serious or fatal injuries for middle-aged drivers and a higher incidence for older drivers, reaching a peak of 3.8 per cent for drivers aged over 84. Those drivers aged over 64 were significantly more likely to be seriously or fatally injured in a crash than drivers aged between 35 and 54, while drivers aged over 74 were significantly more likely to be seriously or fatally injured in a crash than drivers in all age groups under age 55. These patterns of driver injury severity are consistent with the hypothesis that older drivers would be more likely to be seriously or fatally injured than younger drivers.

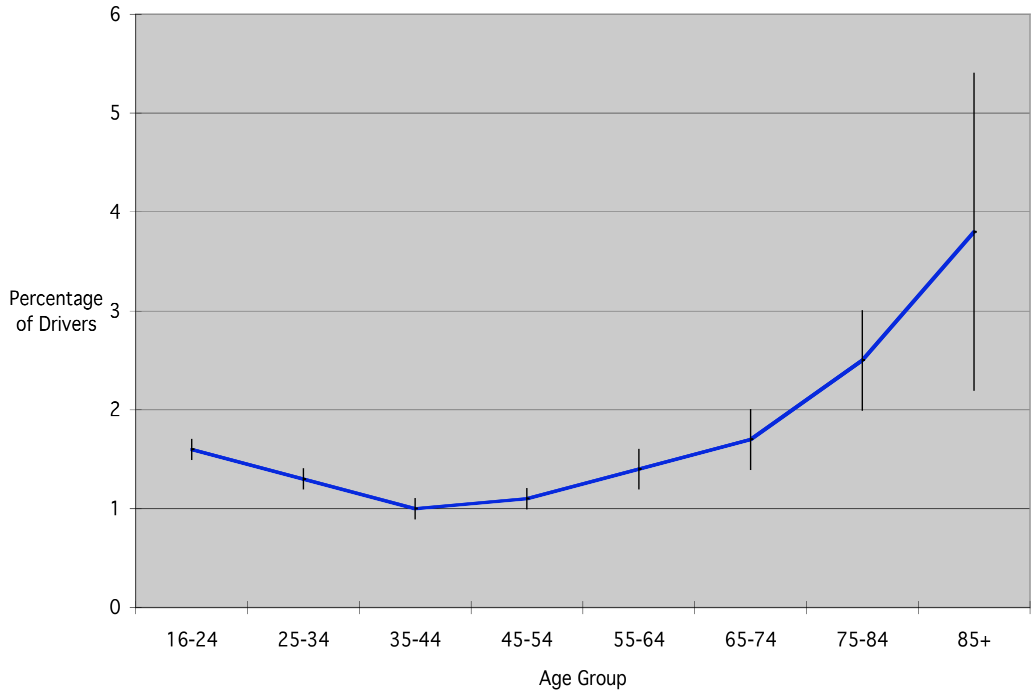

Figure 2.9. Crash-Involved Drivers Who Were Seriously Injured or Killed in the Crash in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.2.3 Intersection Type

With regard to road layout, 51.5 per cent of crashes occurred at an intersection, evenly split between cross roads and T-junctions. However, there was no relationship between driver age and the likelihood of the crash occurring at an intersection (refer to Table 10 in Appendix 2B for data and 99 percent confidence intervals). This is not consistent with predictions based on the literature that older drivers would be over-represented in crashes at intersections.

2.3.2.4 Crash Type

In the TARS database, crashes were categorised into 13 different types. The percentage of crash-involved drivers for each of these crash types is shown in Table 2.4. As can be seen, the most common crash types (i.e. > 10%) were rear end collision, right angle collision, hit parked vehicle and side swipe.

Table 2.4
Number of crash-involved drivers by type of crash in South Australia, 1994 to 1998

Type of Crash	Number	Percentage
Rear end	129,819	39.2
Right angle	68,505	20.7
Hit parked vehicle	40,991	12.4
Side swipe	34,471	10.4
Hit fixed object	18,923	5.7
Right turn	18,637	5.6
Head on	6,062	1.8
Roll over	3,471	1.0
Hit animal	3,366	1.0
Hit pedestrian	2,557	0.8
Left road out of control	2,544	0.8
Hit object on the road	452	0.1
Other	1,792	0.5
Total	331,590	100.0

Examination of crash types enabled testing of the hypothesis that older drivers would be over-represented in right turn crashes. The percentage of crash-involved drivers in each age group involved in right turn crashes is represented in Figure 2.10 (refer to Appendix 2B, Table 11 for data and 99 per cent confidence intervals). Drivers over the age of 74 were significantly more likely to be involved in right turn collisions than drivers in all age groups between the ages of 25 and 64, while drivers aged 65 to 74 were significantly more likely to be in such collisions than middle-aged drivers (aged 35 to 54) only. The tendency for those aged over 64 to have crashes involving a right turn collision is consistent with expectations.

2.3.2.5 Vehicle Movement Before the Crash

The TARS database allows for the coding of 17 different vehicle movements. The percentage of crash-involved drivers executing each of these vehicle movements is shown in Table 2.5. The most common vehicle movement prior to the crash was travelling straight ahead, followed by being stationary on the road.

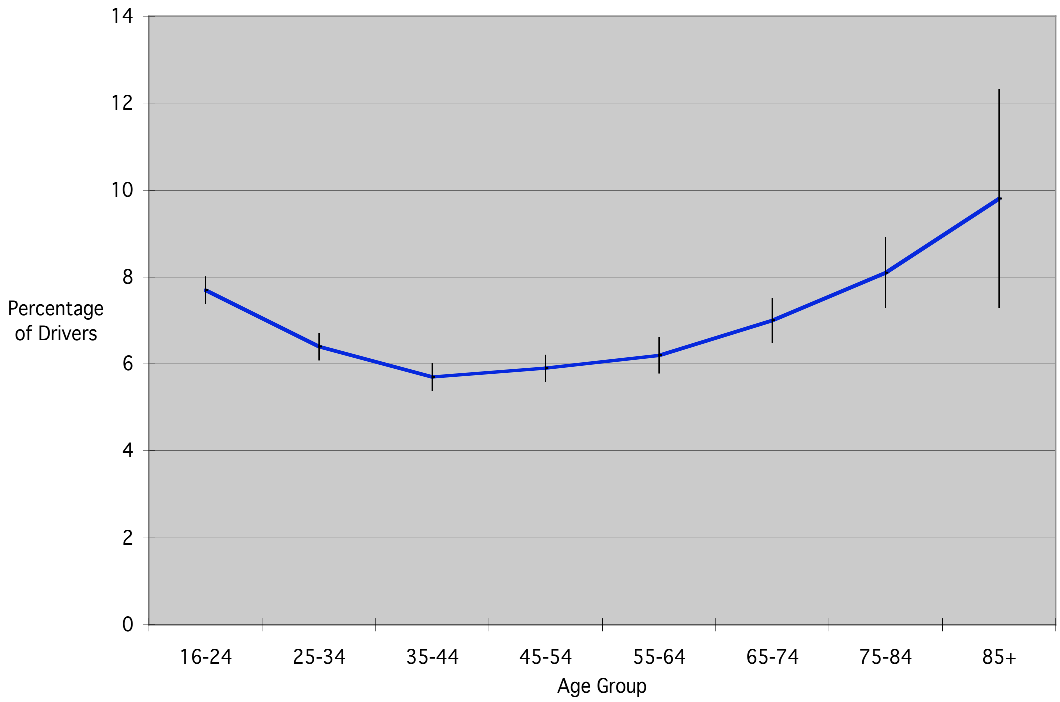

Figure 2.10. Crash-Involved Drivers Who Were Involved in Right Turn Crashes in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Table 2.5
Vehicle movements for crash-involved drivers prior to the crash for South Australia, 1994 to 1998

Vehicle Movements	Number	Percentage
Straight ahead	160,513	48.4
Stopped on road	57,216	17.3
Right turn	25,032	7.5
Parked	24,799	7.5
Swerving	13,538	4.1
Leaving driveway	10,244	3.1
Reversing	8,223	2.5
Left turn	7,175	2.2
Unparking angle	6,083	1.8
U turn	4,253	1.3
Unparking parallel	4,226	1.3
Entering driveway	3,807	1.1
Overtaking on right	2,907	0.9
Parking angle	1,157	0.3
Overtaking on left	1,154	0.3
Parking parallel	1,082	0.3
Other	181	0.1
Total	331,590	100.0

Examination of these vehicle movements enabled testing of the hypothesis that older drivers would be over-represented among crash-involved drivers who were turning prior to the crash. Figure 2.11 shows the greater tendency for older drivers to be turning (right turn, left turn or U-turn) prior to being involved in a crash, peaking at 26.4 per cent of crashes for drivers over 84 compared with less than 14 per cent for each of the age groups under the age of 64 (for data and 99 per cent confidence intervals, refer to Appendix 2B, Table 12). Drivers aged over 64 were significantly more likely to be turning prior to a crash than drivers in all younger age groups, while those over the age of 74 were also significantly more likely to be turning than those aged 65 to 74. This tendency for older drivers to have been turning prior to the crash is consistent with expectations.

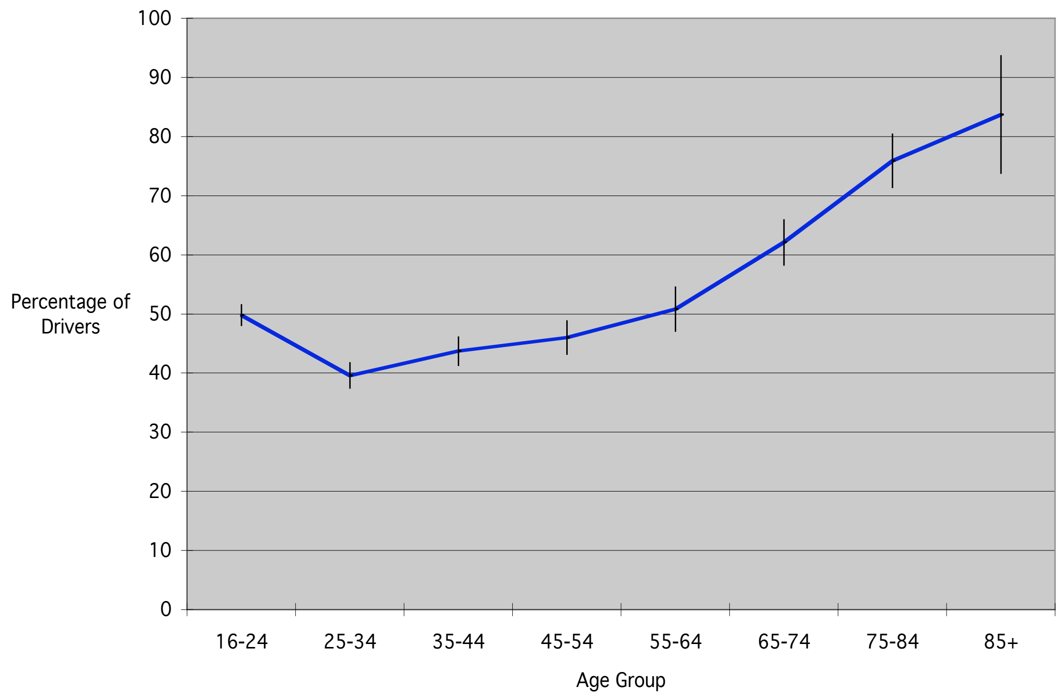

Figure 2.11. Crash-Involved Drivers Who Were Turning Prior to the Crash in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Vehicle movements before the crash were also investigated for right turn crashes only, in order to test the hypothesis that older drivers in right turn crashes would be more likely to be the driver turning right rather than travelling straight ahead. Figure 2.12 depicts the greater tendency for older drivers involved in right turn crashes to be the driver turning right, with incidence rates being over 50 per cent for all age groups over 64, peaking at 83.7 per cent for those aged over 84 (for data and 99 per cent confidence intervals, refer to Appendix 2B, Table 13). Consistent with predictions, older drivers (aged over 64) were significantly more likely to be turning right in right turn crashes than drivers in all other age groups (under 65).

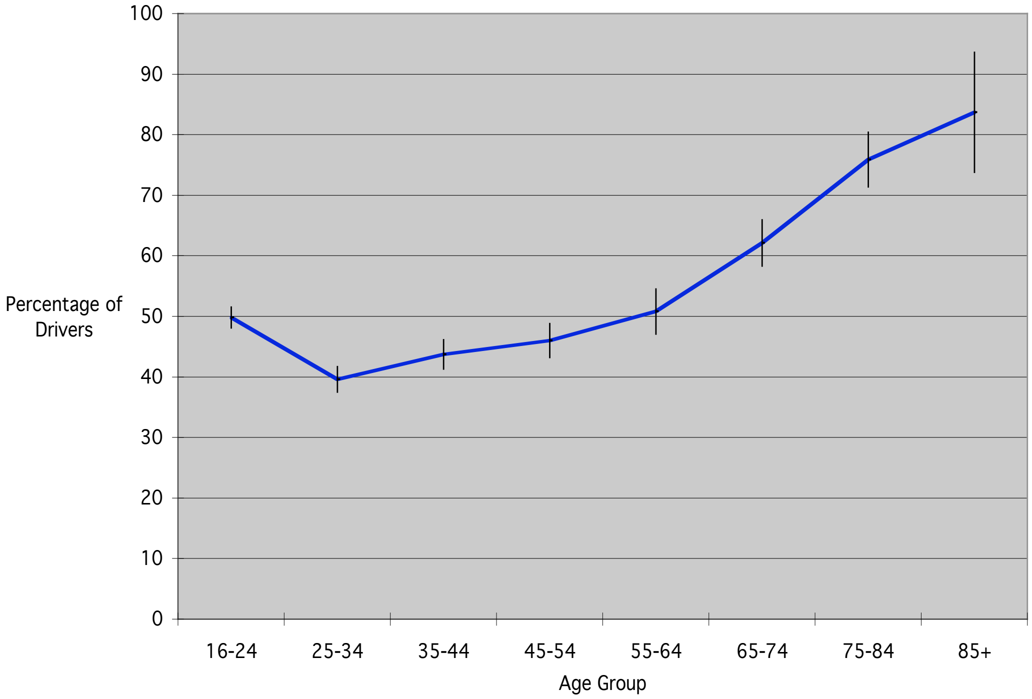

Figure 2.12. Right Turn Crash-Involved Drivers Who Were Turning Right at the Time of the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.2.6 Apparent Driver Error

One of 29 apparent driver errors (including "No error") was assigned by police to each of the crash-involved drivers and recorded in the TARS database. These apparent errors, and the percentage of crash-involved drivers who made them, are provided in Table 2.6. Aside from "No error", the most common driver error assignations (i.e. > 5%) were inattention, failure to give way, and reversing without due care.

Table 2.6

Apparent driver errors by crash-involved drivers in South Australia, 1994 to 1998

Driver Error	Number	Percentage
No errors	168,282	50.8
Inattention	65,481	19.7
Fail to give way	22,621	6.8
Reverse without due care	17,791	5.4
Follow too closely	12,522	3.8
Fail to stand	8,546	2.6
Changed lanes to endanger	6,374	1.9
Vehicle fault	4,054	1.2
Overtake without due care	3,422	1.0
Disobey give way sign	3,356	1.0
Disobey traffic lights	3,250	1.0
Disobey stop sign	2,641	0.8
Fail to keep left	2,516	0.8
Insecure load	2,278	0.7
Excessive speed	1,946	0.6
Incorrect turn	1,371	0.4
Fail to give way right	1,367	0.4
Opening or closing door	1,006	0.3
Drunken pedestrian	885	0.3
Dangerous driving	742	0.2
Misjudgement	178	0.1
Brake failure	172	0.1
Died/sick/asleep	146	0.0
Incorrect or no signal	94	0.0
Broken windscreen	8	0.0
Disobey railway signal	4	0.0
Disobey police signal	4	0.0
Driving under the influence (DUI)	1	0.0
Other	532	0.2
Total	331590	100.0

Examination of apparent driver errors enabled testing of the hypothesis that older drivers would be more likely to disobey either traffic lights, Stop signs or Give Way signs prior to being involved in a crash. The percentage of crash-involved drivers in each age group who were judged by the police to have disobeyed either traffic lights, a Stop sign or a Give Way sign is shown in Figure 2.13, demonstrating the increase with age in these types of driver errors (refer to Appendix 2B, Table 14 for data and 99 per cent confidence intervals). Less than four per cent of crash-involved drivers in each age group under the age of 64 made one of these errors prior to crashing, compared with a high of 11.4 per cent for drivers over the age of 84. Drivers aged over 64 were significantly more likely to have made one of these errors than drivers in all younger age groups, while those over the age of 74 were also significantly more likely to have made one of these errors than those in the 65 to 74 year old age group. This is consistent with expectations.

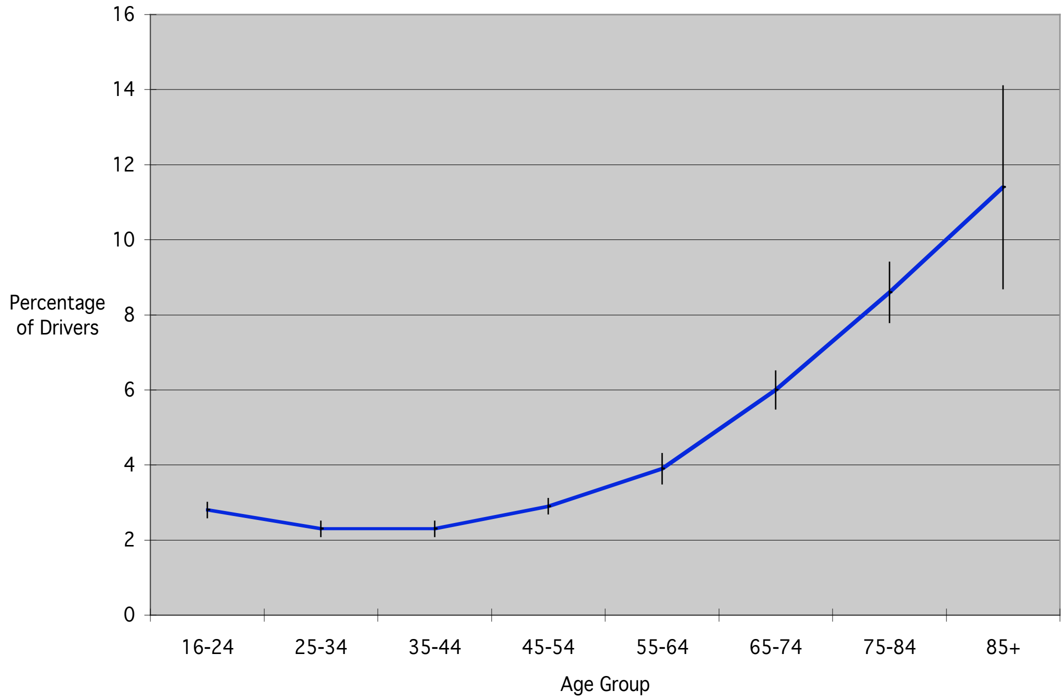

Figure 2.13. Crash-Involved Drivers Who Disobeyed a Traffic Signal, Stop Sign or Give Way Sign in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.2.7 Driver's Responsibility for the Crash

For each crash, the police also determined which driver was most responsible for the occurrence of the crash and this variable was included in the TARS database. In the years from 1994 to 1998, approximately half (49.2%) of the crash-involved drivers were deemed to have been responsible for the crash. The percentage of drivers in each age group listed as responsible for the crash in which they were involved is shown in Figure 2.14 (refer to Appendix 2B, Table 15 for data and 99 per cent confidence intervals).

As illustrated by the graph in Figure 2.14, the drivers most likely to have been deemed to be responsible for crashes in which they were involved were older drivers, especially those aged 75 and over (67.6% for drivers aged 75 to 84 and 80.9% for drivers aged over 84; significantly greater than all other age groups). Those least likely to have been deemed responsible were middle-aged drivers (42.0% for drivers aged 35 to 44 and 41.2% for drivers aged 45 to 54; significantly less all other age groups). The finding of increased likelihood of responsibility for the crash for older drivers is consistent with expectations.

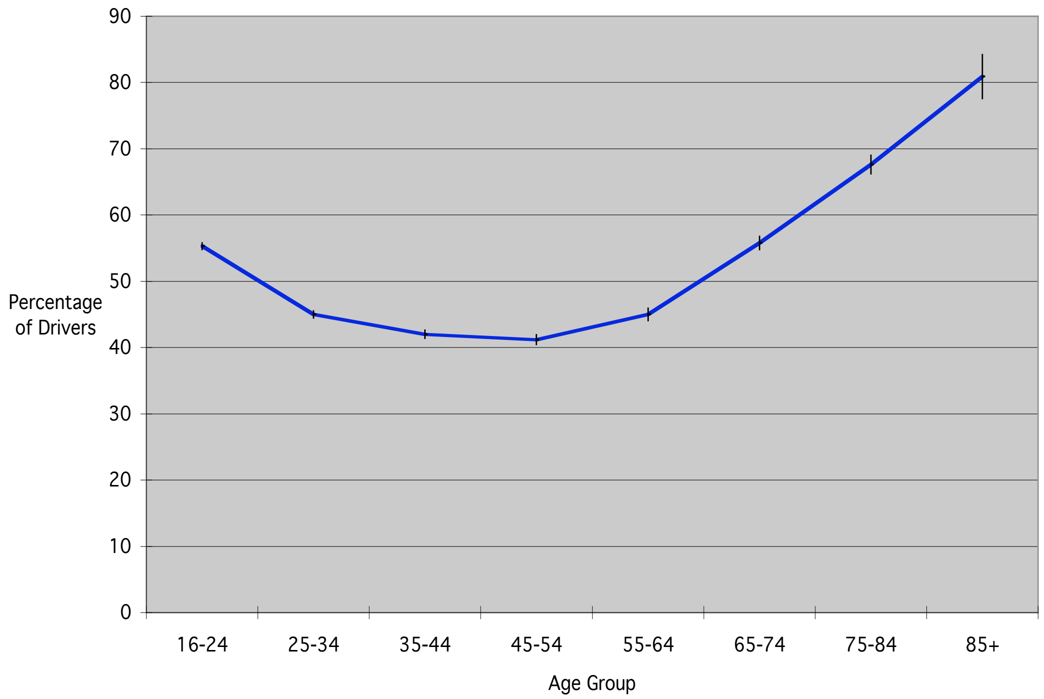

Figure 2.14. Crash-Involved Drivers Deemed to be Responsible for the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.2.8 Excessive Speed

Only a small percentage (0.6%) of crash-involved drivers were deemed by the investigating police officer to have been driving at an excessive speed at the time of the crash. However, this figure is likely to underestimate the occurrence of crashes involving excessive speed, due to the difficulty inherent in reconstructing crash events to obtain a legally sustainable estimate of travelling speed before the crash. As a result of this small number of crashes being attributed to drivers travelling at excessive speed, the following analysis of the occurrence of speeding by crash-involved drivers in different age groups is based on a smaller number of drivers than the analyses presented in other sections. It is also assumed for this analysis that this bias against the choice of 'excessive speed' as a cause of crashes is not systematic with regard to the age of drivers involved in the crashes. The percentages of speeding drivers for each age group is depicted in Figure 2.15 (refer to Appendix 2B, Table 16 for data and 99 per cent confidence intervals).

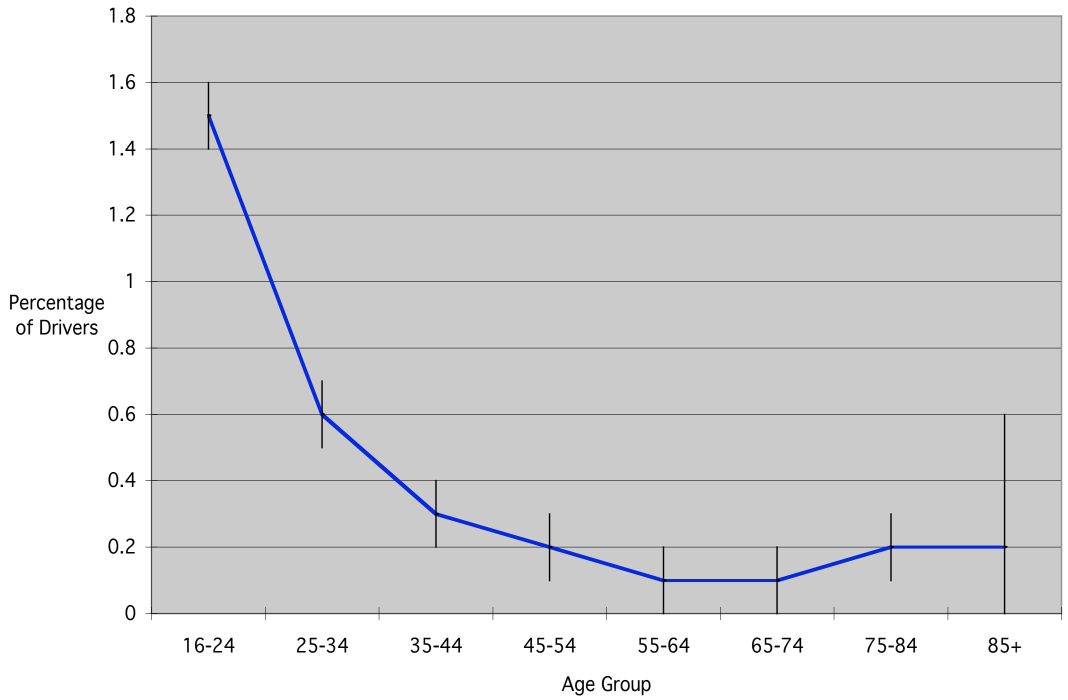

Figure 2.15. Crash-Involved Drivers Deemed to Have Been Driving at Excessive Speed in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Figure 2.15 shows that the percentage of drivers who were deemed to have been speeding at the time of their crash was very small (less than 0.5%) for all age categories except for those under the age of 35. Both middle-aged and older drivers were very rarely deemed to have been speeding at the time of the crash. Drivers aged between 65 and 84 were significantly less likely to have been speeding than drivers aged under 35, while drivers aged over 84 were significantly less likely to have been speeding than those under 25. The finding provides support for the hypothesis that older drivers would be less likely to be speeding prior to being involved in a crash.

2.3.2.9 Driver Blood Alcohol Concentration (BAC)

In South Australia, police have the right to demand a breath test from any crash-involved driver to determine their blood alcohol concentration (BAC). It is also law that all injured crash participants over the age of 14 who are treated at a hospital are required to provide a blood sample for BAC analysis. The BAC data in the TARS database include the results of either of these two testing methods.

The driver's BAC was recorded in the TARS database for only 11,682 (3.5%) of the 331,590 crash-involved drivers. Figure 2.16 shows the percentages of drivers with known BACs across age groups. It reveals that young drivers and old drivers, rather than middle-aged drivers, were more likely to have a known BAC. These age differences are likely to be due to age differences in the likelihood of a crash having a high degree of injury severity (see section 2.3.2.1). Those crashes with a high injury severity are more likely to involve drivers being breath tested, in addition to the legal requirement that crash participants treated at hospital provide a blood sample for BAC analysis. Illustrating this, Figure 2.16 additionally shows the percentage of crashes for each age category that produced a serious injury (refer to Appendix 2B, Table 17 for the data).

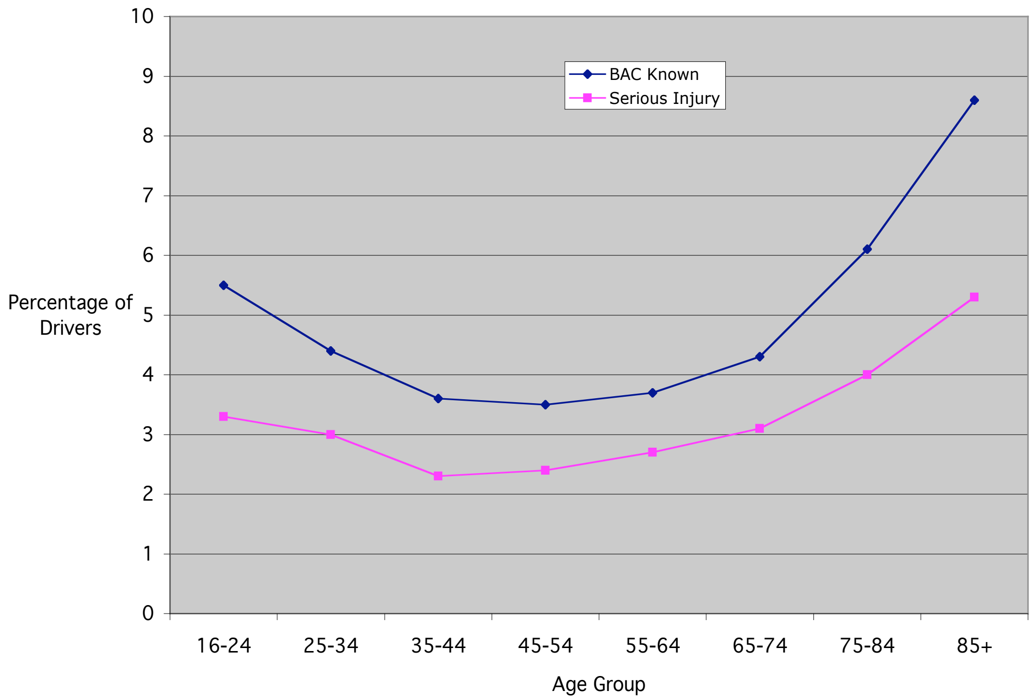

Figure 2.16. Percentage of Crash-Involved Drivers for Whom a Blood Alcohol Concentration was Known and Whose Crashes Produced a Fatal or Serious Injury for One or More Crash Participants in South Australia 1994 to 1998, by Age Group

The percentage of crash-involved drivers in each age group for whom a BAC was recorded and who registered a BAC over the legal limit in South Australia of 0.05 g/100ml is represented graphically in Figure 2.17 (refer to Appendix 2B, Table 18 for data and 99 per cent confidence intervals). There are clear effects of age on the likelihood of crash-involved drivers having had an illegal blood alcohol concentration, with younger drivers having been more likely than older drivers to have been drink driving when they crashed. There were significant decreases in driving with an illegal BAC at the time of a crash with each consecutively older age group over the age of 35 years. Among the 81 drivers aged over 84 for whom a BAC was recorded, not a single driver registered a positive BAC (> 0.00 g/100ml). This lower likelihood of older drivers drink driving at the time of a crash conforms with predictions.

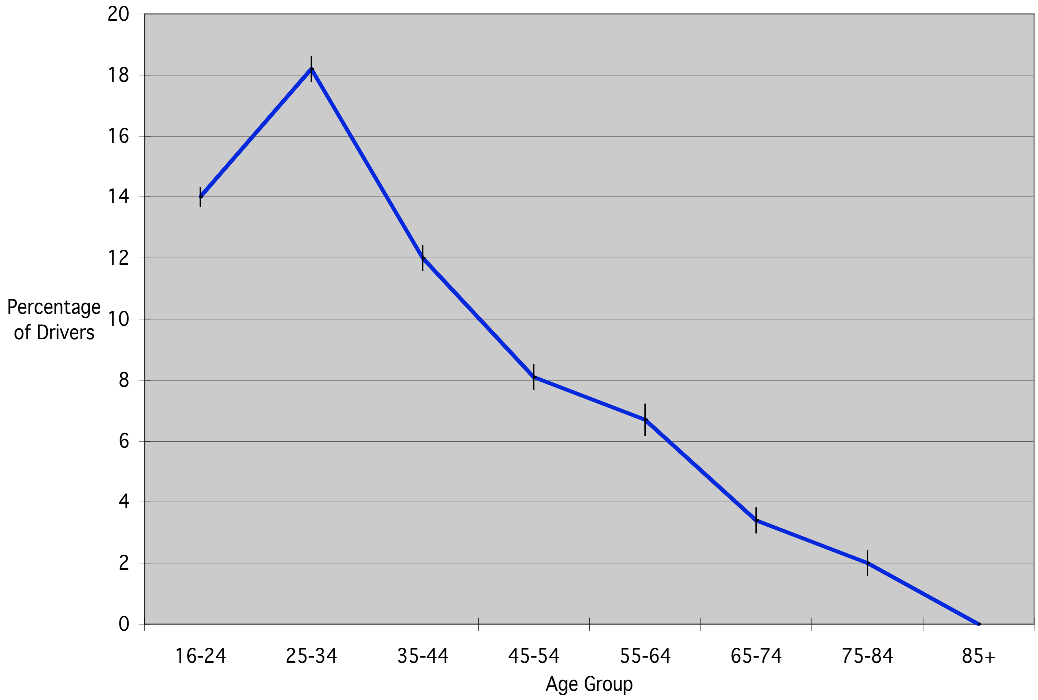

Figure 2.17. Crash-Involved Drivers with a Blood Alcohol Concentration over 0.05 g/L in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.2.10 Crash Characteristics: Summary

The preceding sections revealed that older drivers (aged 65 and over) were more likely than younger drivers (aged under 65) to be involved in serious injury crashes and also to be seriously injured themselves. No differences were found between age groups, however, in the likelihood of crashes occurring at intersections. There were increases with age in the likelihood of right turn crashes, in the likelihood that crash-involved drivers were executing turning movements just prior to the crash, and in the likelihood that right turn crash-involved drivers, specifically, were turning right. Older drivers were also more likely than younger drivers to have disobeyed traffic lights, Give Way signs or Stop signs prior to the crash. In addition, investigating police officers were more likely to have determined older drivers to have been responsible for the crash than younger drivers. Older drivers, however, were less likely than younger drivers to have been speeding prior to the crash or to have had an illegal BAC at the time of the crash.

Therefore, except for the failure to find age differences in the likelihood of crashes occurring at intersections, the results provided support for the hypotheses relating to age differences in the characteristics of crashes that drivers are involved in.

2.3.3 Conditions in Which Crashes Occur

The following sections are concerned with the conditions in which crashes tended to occur for different age groups. The variables included in this section are hour of the day (2.3.3.1), ambient light (2.3.3.2), wetness of the road (2.3.3.3), and presence of rain (2.3.3.4).

2.3.3.1 Hour of Day

The time of the day when a crash occurred was recorded in the TARS database. The data for the percentage of crashes by age group occurring in the two peak traffic times combined (0700 to 0900 and 1700 to 1900) are represented in Figure 2.18 (refer to Appendix 2B, Table 19 for data and 99 per cent confidence limits). Over 25 per cent of crashes occurred during peak hour traffic for all age groups under the age of 55, while the figures were less than 15 per cent for all age groups over the age of 74. There were significant differences between those aged over 64 and every age group under 65, and between those aged over 74 and every age group under 75. This finding that older drivers are less likely to crash during peak traffic times is consistent with expectations.

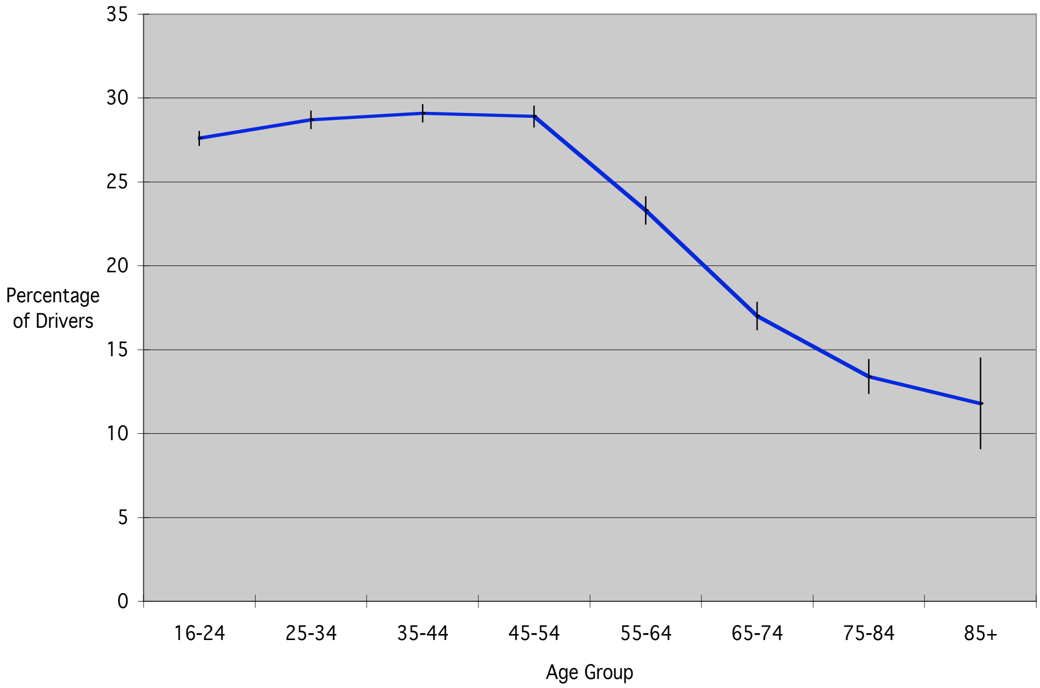

Figure 2.18. Crash-Involved Drivers Who Crashed During Peak Traffic Times in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.3.2 Ambient Light

The level of ambient light for each crash was recorded in the TARS database as being daylight, dawn/dusk, or night. Overall, 17.2 per cent of crashes occurred in darkness, 1.4 per cent occurred at either dawn or dusk, and the remainder occurred in daylight. Examination of age differences revealed that crashes among drivers over the age of 64 were significantly more likely to have occurred in daylight compared with crashes of drivers in all younger age groups. Over 90 per cent of crashes involving drivers aged over 64 occurred in daylight, while the corresponding figure for drivers aged under 25 was less than 75 per cent. The percentages of crashes occurring in daylight for the different age groups is depicted in Figure 2.19 (refer to Appendix 2B, Table 20 for data and 99 per cent confidence intervals). These findings support the hypothesis that older drivers are more likely to be involved in a crash in daylight hours.

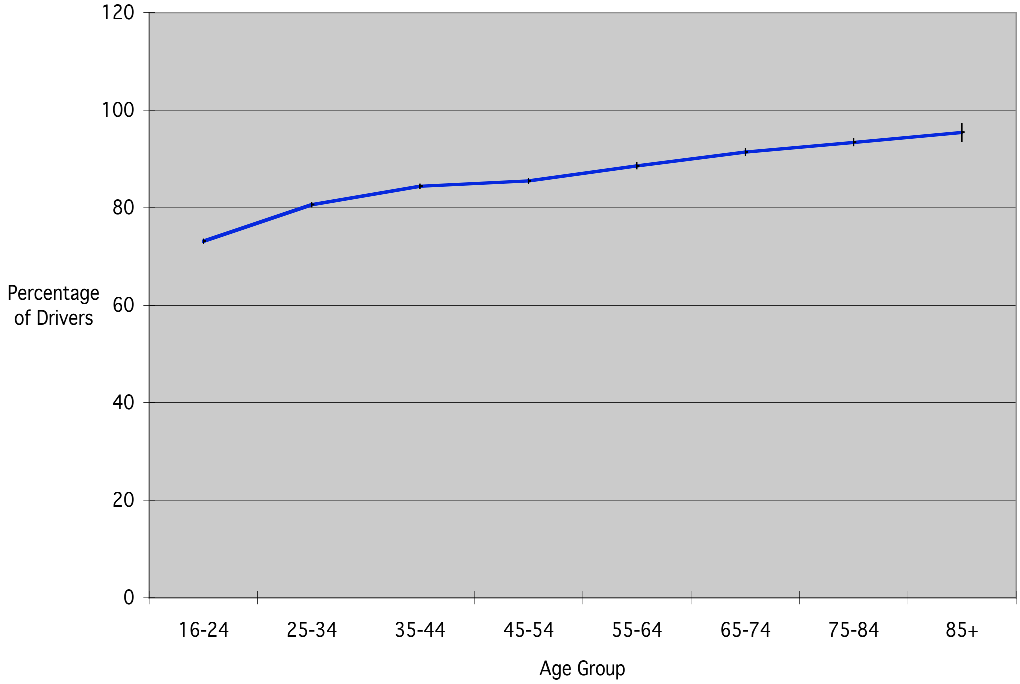

Figure 2.19. Crash-Involved Drivers Who Crashed During Daylight in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Interval*s*

2.3.3.3 Wetness of the Road

In the TARS database, the roads on which the crashes occurred were coded as either wet or dry, and the data for this variable for each age group are represented in Figure 2.20 (refer to Appendix 2B, Table 21 for data and 99 per cent confidence limits). Overall, 13.4 per cent of crashes occurred on roads that were wet at the time. The incidence of crashes on wet roads decreased with age, with less than ten per cent of crashes occurring on wet roads for drivers aged over 74, while over 15 per cent of crashes occurred on wet roads for drivers aged under 25. The likelihood of an older driver being involved in a crash on a wet road was significantly less than that of drivers in every age group under 65. The decreasing tendency with age to be involved in crashes on wet roads is consistent with expectations.

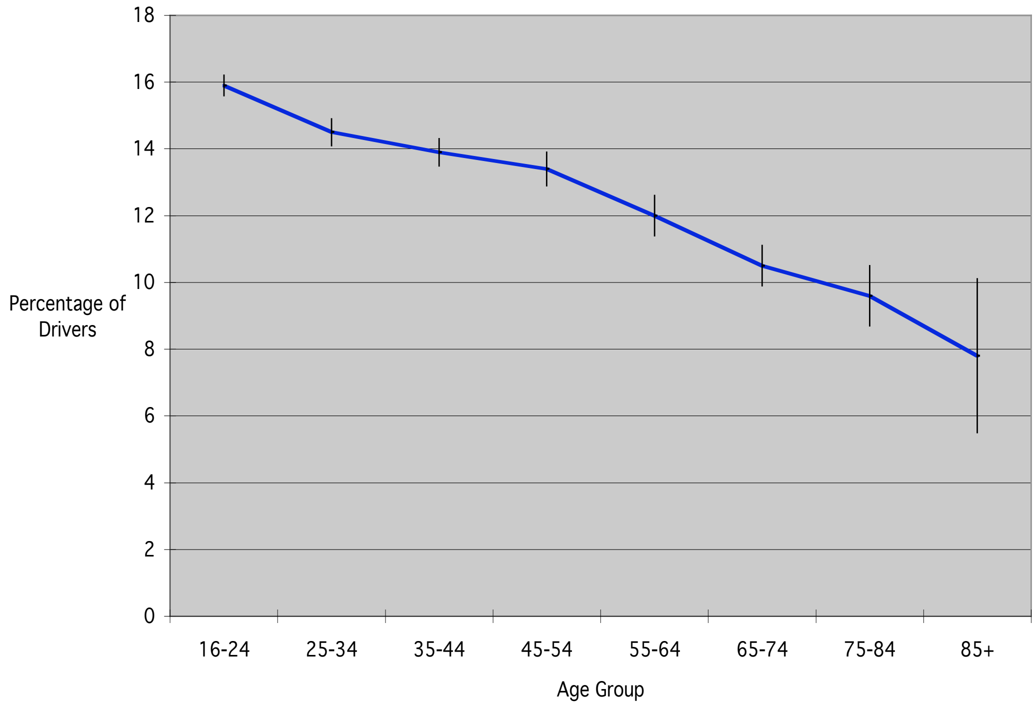

Figure 2.20. Crash-Involved Drivers Who Crashed on Wet Roads in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.3.3.4 Presence of Rain

Mirroring the results for road wetness (section 2.3.3.3), crashes during rain were in the minority (9% overall). Crashes during rain decreased in frequency with increasing age, as demonstrated in Figure 2.21 (refer to Appendix 2B, Table 22 for data and 99 per cent confidence intervals). Over ten per cent of crashes involving drivers under the age of 25 took place during rain, compared with less than seven per cent of crashes for those aged over 74. Drivers over the age of 64 were significantly less likely to be involved in a crash during rain than drivers in every age group under the age of 65. These findings are consistent with expectations.

2.3.3.5 Conditions in Which Crashes Occur: Summary

The preceding sections reveal that older drivers (aged over 64) were significantly less likely than younger drivers (aged under 65) to be involved in a crash during peak traffic times (0700 to 0900 and 1700 to 1900), to have crashed in hours of darkness, or to have crashed on a wet road or in the presence of rain. These results were all consistent with hypotheses.

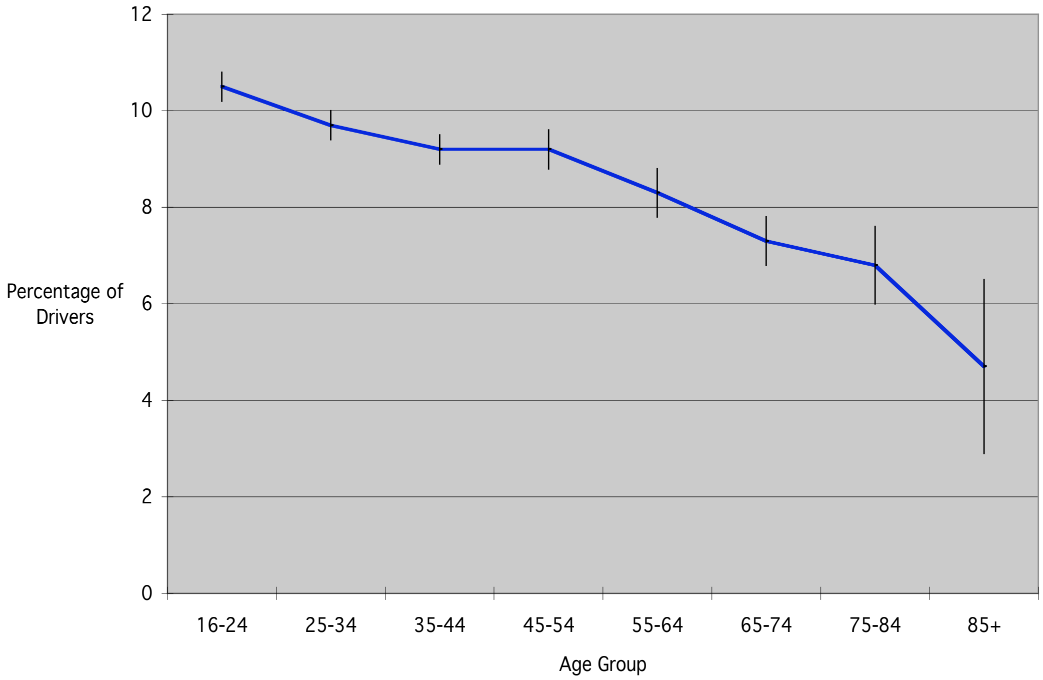

Figure 2.21. Crash-Involved Drivers Who Crashed in the Presence of Rain in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

2.4. Discussion

This chapter represents an attempt to determine whether previously reported relationships between aging and road crash involvement were also present in the crash data of South Australians over a five year period. A number of hypotheses were generated from a review of the literature on aging and driving, and these hypotheses were tested using the crash data for the years 1994 to 1998 from the Traffic Accident Reporting System, a database of all crashes reported to the police in South Australia. The hypotheses tested were concerned with the *numbers* of crashes of drivers in different age groups, the *characteristics* of the crashes involving drivers in different age groups, and the *conditions* in which crashes tended to occur for drivers in different age groups.

2.4.1 Number of Crashes

Consistent with predictions, increasing age was associated with decreases in the total number of crashes, in crashes per head of population, and in crashes per licensed driver. When crash rates were adjusted according to annual kilometres driven by those in different age groups, the highest crash rates were exhibited by the youngest drivers (aged under 25) and by the oldest drivers for whom crashes per kilometres driven could be computed (aged over 74). This was also consistent with predictions. Drivers aged between 65 and 74, however, did not have a degree of crash involvement greater than middle-aged drivers.

In keeping with previous findings (OECD, 2001), this pattern of crash involvement suggests that older drivers have a lower absolute risk of being involved in a crash, compared with younger drivers, but that this lower risk is partially due to older licensed drivers doing less driving, on average, than licensed drivers in younger age groups. However, as discussed in section 1.3.6, the increased rate of crash involvement that is apparent when the data are expressed in terms of crashes per kilometre driven may not be due to increased crash risk but, rather, an increased risk of injury (Eberhard, 1996; Evans, 1991b; Fife, Barancik, & Chatterjee, 1985; Hakamies-Blomqvist, 1998; Maycock, 1997; OECD, 2001). This increased risk of injury of older drivers would make it more likely that their crashes are included in crash databases, for which inclusion is partly or wholly determined on the basis of the crashes being severe enough to cause an injury. Inclusion in the TARS database is partly determined by the occurrence of injury as a result of the crash, and, as older drivers are more likely to be injured, their crashes would be more likely to be included in this database. However, the fact that crashes producing only property damage are also included in the TARS database may reduce this bias. In fact, when rates for crashes causing property damage only were looked at, those aged over 74 still had higher rates per kilometre driven than middle-aged drivers.

It could also be the case that the increased rate of crash involvement of older drivers per kilometre driven is due to low mileage bias (Hakamies-Blomqvist, 2003). It is known that those who drive more (those with a high yearly “mileage”) have less crashes per kilometre driven than those who drive less, because they amass much of their elevated yearly mileage on relatively safe roads such as freeways (Janke, 1991). As older drivers, such as those in the sample used in this study, tend to drive less than younger drivers, their lower mileage as a group will increase the likelihood that they have a higher crash rate per kilometre driven. Hakamies-Blomqvist (2003) has argued that if you match older and younger drivers on yearly mileage, the differences in crash rates between the groups disappear (for a full discussion of this issue, see section 1.3.7).

2.4.2 Crash Characteristics

With regard to crash characteristics, it was found that older drivers were more likely than younger drivers to be involved in crashes resulting in serious or fatal injuries, and to suffer such injuries themselves. This relationship between aging and involvement in crashes producing serious injuries has been reported previously and attributed to older drivers’ frailty relative to younger drivers (OECD, 2001).

Another hypothesis that was tested by this study was that older drivers would be over-represented in crashes occurring at intersections. The current data, however, did not reveal a greater rate of crashes at intersections for older drivers. This may be due to the fact that crashes can occur at intersections which are not related to problems negotiating intersections. For example, the most common crash type for this sample of crash-involved drivers was the rear end collision. The percentage of drivers involved in rear end collisions whose crashes occurred at intersections was 60%, compared with 46% for other crash types. Rear end collisions are generally related to following too closely, misjudging the severity of braking of lead vehicles, or inattention. With increasing age, there is a decreasing tendency to be involved in rear end collisions (over 40% of crash-involved drivers were involved in rear end collisions for all age groups between 25 and 64, compared with 31.8% for those aged 65-74, 23.6% for those aged 75 to 84, and 16.5% for those aged over 84). When it is claimed that older drivers have trouble at intersections, researchers are referring to their increased likelihood of being involved in crashes such as right angle and right turn crashes that reflect difficulties negotiating intersections. It is possible that there was no relationship between aging and crashing at intersections because any effect of older drivers having problems negotiating intersections was reduced by large numbers of younger drivers being involved in crashes at intersections that were not caused by such problems.

Supporting the hypothesis that older drivers do make more intersection-specific errors were the findings that they were over-involved in right turn collisions, were more likely to have been turning at the time of the crash, were more likely to have been the right-turning driver in right turn crashes, and were more likely to have disobeyed a traffic signal, Give Way or Stop sign prior to colliding with another vehicle. All of these patterns of crash involvement were predicted on the basis of the literature (Preusser et al., 1998).

This tendency to be involved in intersection-type crashes could be due to one or more of three things. First, it could be due to intersection-specific errors, which, in turn, are thought to be due to the difficulties with increased age in dividing attention between competing tasks, dealing with a cluttered visual array, coping with conflicts based in the periphery of the visual field, and undertaking these competing demands under time pressure (Hu, Trumble, & Lu, 1995; Janke, 1994). Such difficulties with age are thought to be due to declining visual and attentional abilities, and slowed speed of response (Staplin et al., 1998a). Secondly, the relationship between aging and intersection crash involvement could be due to changes in driving patterns, such that older drivers are more likely to drive in daylight when multiple vehicle crashes are more likely to occur (Eberhard, 1996). Thirdly, it could be due to the increased frailty of older drivers, meaning that they are more likely to be injured in low speed intersection crashes than younger drivers and, therefore, that their intersection crashes are more likely to appear on crash databases utilising injury occurrence as one of the criteria for inclusion (Preusser et al., 1998).

Another finding that is consistent with the literature (Cooper, 1990a) was that there was a relationship between aging and responsibility for the crash, with older drivers being more likely to be deemed by the investigating police officer to be responsible for their crash involvement than were younger drivers. Hakamies-Blomqvist (1996) has suggested that the increase among older drivers in rates of responsibility for crashes could be due to reductions in not-at-fault crashes. These reductions could be due to slower, more conservative driving styles that mean older drivers are less likely to strike another vehicle being driven by someone who has made a mistake, and are therefore less likely to strike another vehicle as the not-at-fault driver (Hakamies-Blomqvist, 1996; Keskinen et al., 1998). However, if the more conservative driving styles represent compensation for decreased visual capabilities and increased reaction time, it is possible that the net result is a likelihood of being involved in not-at-fault crashes that is comparable to drivers in other age groups. It could also be the case that police officers are more likely to assign responsibility for crashes to older drivers because of negative stereotypes about their driving ability (Fildes, 1997).

This study also found that older drivers were less likely than younger drivers to have been driving with an illegal BAC or at excessive speed when involved in crashes, which is consistent with previous studies looking at the contribution of alcohol (Hakamies-Blomqvist, 1994) or excessive speed (OECD, 2001) to crashes involving older drivers. Thus, crashes involving older drivers do not appear to be due to the deliberate, risk-taking actions often implicated in the crashes of younger drivers (Eberhard, 1996).

2.4.3 Conditions in Which Crashes Occur

As predicted, older drivers were less likely to be involved in a crash in peak hour traffic, in hours of darkness, or in wet weather conditions. These findings are consistent with the literature (Eberhard, 1996; OECD, 2001; Ryan et al., 1998). As such conditions would be likely to prove more difficult for older drivers with visual and other functional impairments, it would be expected, given equal amounts of driving exposure, that older drivers would be over-represented in crashes in these conditions. The common finding that the opposite is the case is thought to reflect reduced exposure, through choice, to these potentially troublesome driving conditions (Eberhard, 1996).

2.4.4 Summary

In summary, the pattern of older driver crash involvement in South Australia, based on police reported crashes from 1994 to 1998, reflects those patterns routinely reported in the road safety literature. Older South Australian drivers (those aged over 65) have less crashes than younger drivers, but have a higher crash rate per kilometre driven. They are more likely to sustain serious injuries, which could be one of the reasons for their elevated crash rate. They tend to be involved in crashes related to problems associated with negotiating intersections, especially when having to perform turning manoeuvres.

They are more likely than younger drivers to be found responsible for their crashes but are less likely to have an illegal BAC or to have been speeding when the crash occurred. They are also less likely to crash in adverse driving conditions, including peak hour, night time and wet weather, which is thought to be due to selective driving patterns.

The questions facing road safety authorities, who are considering the crash involvement patterns of older drivers, is whether age-related differences in crash patterns can be explained, and whether there are any means by which the rates of older driver crash involvement can be reduced. The following chapter (Chapter 3) reviews the literature concerning explanations for the increases in the crash risk of older drivers in terms of medical conditions and functional impairments. This is followed by a chapter reviewing the possible responses to the greater crash risk of older drivers, including the identification of individual older drivers with a higher than average crash risk (whose licences may then revoked), and the possibility that the majority of older drivers can assess their own driving competence and adjust their driving behaviour accordingly ("self-regulation"). If older drivers are able to restrict their driving in accordance with their driving ability, then it may be possible for their crash involvement to be reduced with only minimal restriction of mobility. The findings in the present chapter indicate that South Australian older drivers exhibit crash involvement patterns similar to older drivers in other jurisdictions, suggesting that the results of subsequent studies are likely to be generalisable to older drivers elsewhere.

CHAPTER 3: RISK FACTORS FOR CRASH INVOLVEMENT AMONG OLDER DRIVERS

3.1 Introduction

Although an increase in crash risk with age, demonstrated in Chapters 1 and 2, suggests a decline in driving ability among older adults, it is possible that this overall decline masks substantial heterogeneity within this age group. It is well-established, for example, that declines with age in cognitive abilities vary markedly between individuals (Daigneault, Joly, & Frigon, 2002a; Hakamies-Blomqvist, 1998; Klavora & Heslegrave, 2002) and it is possible that drivers, too, 'age' at different rates (Cushman, 1996). It is possible that there are subgroups of older drivers with an especially high risk of crashing, while the remainder have a low risk, even as low as that for middle-aged drivers. The presence of subgroups of older drivers with an elevated crash risk could mean that the distribution of crash risk for older drivers is bimodal or multi-modal rather than normal (Hakamies-Blomqvist, 1998), a notion supported by the finding that most older drivers have crash-free records (Evans, 1991b). This chapter summarises research that has been designed to identify the characteristics of drivers with an elevated crash risk. Most of this research has been focussed either on drivers affected by medical conditions or on those affected by functional impairments.

3.2 Medical Conditions and Crash Involvement

The possibility that there are high risk subgroups of older drivers is intuitively appealing, given that, with increasing age, there are increases in the number of drivers affected by medical conditions that may affect driving ability (Hull, 1991; Janke, 1994; Klavora & Heslegrave, 2002; Luscz, 1999; OECD, 2001; Reuben, Silliman, & Traines, 1988; Vernon et al., 2002; Wallace & Retchin, 1992; Waller, 1991). If crash risk were explicable solely in terms of the effects of medical conditions, then all reference to age per se would be unnecessary. Rather, the increased crash risk of older drivers could be re-conceptualised as the increased crash risk of drivers affected by illness. The remainder of this section provides details of research into the relationship between medical conditions and measures of crash involvement or reduced on-road driving ability.

3.2.1 Eye Diseases

A specific group of diseases that increase in prevalence with age and that are likely to be related to driving problems is that of diseases of the eye. There are four main diseases of the eye that are more common with increasing age and that have been identified as potentially causing problems for driving. These are cataract, glaucoma, macular degeneration and diabetic retinopathy (Klein, 1991).

Cataract is caused when protein particles in the lens grow to a size sufficient to cause light scatter, resulting in losses in contrast sensitivity, losses in visual acuity, and difficulties coping with glare (Cole, 2002; Staplin et al., 1998a). It is the leading cause of visual impairment in older adults (Owsley, Stalvey, Wells, & Sloane, 1999) and in Australia has been reported to affect 70% of those aged 65 to 74, 85% of those aged 75 to 84, and nearly 100% of those aged over 85 (Mitchell, Cumming, Attebo, & Panchapakesan, 1997). It has been linked to both increased crash risk (Owsley et al., 1999) and poorer driving performance (Wood & Troutbeck, 1994, 1995) but its effects can be considerably ameliorated by undergoing a surgical procedure involving the removal of the crystalline lens and subsequent intraocular lens insertion (Owsley et al., 1999). Post-surgery, drivers have reported a reduction in visual complaints when driving (Monestam & Wachtmeister, 1997), less driving difficulty (Elliott, Patla, Furniss, & Adkin, 2000), and increases in the amount of driving done (Owsley, 2002). Reductions in crash involvement (Owsley, 2002) and improvements in driving performance (Wood, 2002b) relative to control groups have also been found following cataract surgery.

Macular degeneration involves deposits of material on the back layer of the eye that can damage the retina. This leads to the loss of central, or foveal, vision, and in a driving context means that drivers are unable to see other cars or read road signs (Klein, 1991). A USA study reported that macular degeneration affects 18% of those aged 52 to 64, 26% of those aged 65 to 74 and 36% of those aged 75 to 85 (Sperduto & Seigel, 1980). Although its prevalence is not as high as that of cataract, it is the leading cause of blindness in those over the age of 60 (Staplin et al., 1998a). As macular degeneration affects foveal vision first, it is very noticeable and quickly affects the visual abilities necessary for driving. This may explain why macular degeneration is not related to crash involvement but is related to cessation of driving (Campbell, Bush, & Hale, 1993; Eberhard, 1996). Driving cessation and its correlates are discussed in a later section (section 4.3.4).

Glaucoma is the second leading cause of blindness in those over 60, behind macular degeneration, and is caused by high intraocular pressure. Its prevalence in a North American sample was 1% between the ages of 52 and 64, 5% for those aged 65 to 74, and 7% for those aged 75 to 85 (Kahn & Milton, 1980). The higher intraocular pressure that characterises glaucoma results in destruction of optic nerve fibres and is experienced by the sufferer as a gradual shrinking of the visual field (Staplin et al., 1998a). As the loss of peripheral vision in the early stages of glaucoma is gradual, people affected by it often do not realise it is happening (Klein, 1991). It has been linked to greater crash involvement (Eberhard, 1996; Wood, 2002b)

As its name suggests, diabetic retinopathy is an eye condition secondary to diabetes. It involves the loss of blood flow to the retina and the consequent pathological generation of new blood vessels. It commonly leads to loss of colour discrimination and reduced contrast sensitivity. At its worst, it can lead to haemorrhaging and blindness (Klein, 1991). As retinopathy is one of a number of conditions associated with diabetes (Janke, 1994), its potential to influence crash risk is likely to be difficult to separate from other diabetes-related conditions.

3.2.2 Dementia

Dementia is a broad term encompassing a number of different disorders, all of which involve global cognitive decline (Lezak, 1995). There are a number of different forms of dementia but the most common is Dementia of the Alzheimer's Type (DAT). DAT affects 12 to 15% of those aged over 65 and around half of those aged over 85 (Fildes, 1997), and has been identified as the most common cause of abnormal cognitive decline in older adults (Roush, 1996). Other types of dementia include Lewy body dementia, vascular or multi-infarct dementia, Pick's disease, Frontal Lobe dementia, Parkinson's disease, Huntington's disease, progressive supranuclear palsy, and HIV dementia (Lezak, 1995).

DAT is classified according to three main stages: mild, moderate and severe (Fildes, 1997). Mild dementia is characterised by the diminished ability to respond to novel stimuli (Fildes, 1997), and by attentional and memory deficits (Parasuraman & Nestor, 1991). At the mild stage, DAT is difficult to diagnose, especially for those with high premorbid functioning (Parasuraman & Nestor, 1991) because it resembles the effects of normal aging (Storandt & Hill, 1989). In addition to a worsening of symptoms, those affected by moderate DAT exhibit general disorientation, lack of insight and lack of competence, while those with severe DAT are no longer able to function independently and, at this late stage, there is no question of driving (Fildes, 1997).

A number of studies have been conducted to determine the extent to which DAT produces an increase in crash risk for older drivers. Most studies have found that dementia does lead to an increased risk of road crashes (Carr, Jackson, & Alquire, 1990; Cooper, Tallman, Tuokko, & Beattie, 1993b; Dieter & Wolf, 1989; Dubinsky, Williamson, Gray, & Glatt, 1992; Friedland et al., 1988; Johansson, Bogdanovic, Kalimo, Winblad, & Viitanen, 1997; Kaszniak, 1991; Lucas-Blaustein, Filipp, Dungan, & Tune, 1988; O'Neill et al., 1992), although there have been studies finding no increase in risk during the very early stages of dementia (Carr, Duchek, & Morris, 2000; Drachman & Swearer, 1993; Trobe, Waller, Cook-Flannagan, Teshima, & Bieliauskas, 1996; Waller, Trobe, Olsen, Teshima, & Cook-Flannagan, 1993). Dementia has also been found to negatively affect driving performance on the road (Fitten et al., 1995; Hunt, Morris, Edwards, & Wilson, 1993) and on a driving simulator (Rizzo, McGehee, Dawson, & Anderson, 2001).

It has additionally been argued that DAT poses a problem for road safety because, unlike stroke which produces a sudden deficit in functioning (see section 3.2.3), it is not brought to the attention of sufferers or medical authorities by a traumatic event. DAT is only discovered after functioning has deteriorated to the point at which the person with dementia seeks a diagnosis or is referred for one by a relative (Cooper et al., 1993b). It is also problematic because the decline in functions relevant to driving is combined with a progressive decline in the ability to monitor one’s own behaviour and performance, meaning that drivers with dementia are less likely to detect declines in their own driving ability (Lundberg et al., 1997).

Although dementia has a clear link to crash involvement and declining driving performance, the general consensus is that a diagnosis of dementia should not lead to the automatic cancellation of a driver’s licence (Lundberg et al., 1997; OECD, 2001). Group decrements on indices of driving ability conceal considerable variation between individuals with dementia. In studies comparing samples of healthy older adults with drivers diagnosed with dementia, many drivers within the dementia samples have displayed driving performance and crash records comparable to healthy drivers matched for age, despite declines in ability or increases in crashes for the dementia groups as a whole (Drachman & Swearer, 1993; Hunt et al., 1993; Lundberg et al., 1997; Rizzo et al., 2001). Given these findings and the finding that driving ability declines with increasing disease severity, it has been argued that those with mild dementia should not automatically have their licence cancelled but that they should be assessed regularly to ensure their driving abilities meet acceptable standards (Hunt et al., 1993; Lundberg et al., 1997). Current Australian guidelines only require driving cessation in the event of "significant impairment" of various functional abilities. The need for regular review of drivers with dementia is also noted (Austroads, 2001 p43).

3.2.3 Cerebrovascular Accidents (CVAs)

Cerebrovascular accidents (or strokes) are traumatic brain events resulting from the disruption of blood flow to a section of the brain. This disruption of blood flow causes the death of the affected brain tissue, due to a lack of oxygen, which, in turn, results in the functions carried out by these areas of the brain being compromised. CVAs may be preceded by one or more smaller strokes, called "transient ischaemic attacks" (TIAs), the symptoms of which resolve in a matter of hours (Lezak, 1995). CVAs are increasingly common with advancing age (Underwood, 1992) and have been identified by Christie (1981) as the most common cause of disability in the industrialised world.

Few studies have been conducted to assess whether CVAs increase driver crash risk. One reason for this is that the design and interpretation of stroke studies is complicated by the large variation in outcomes following a stroke. The effects of a stroke are dependent on the extent and location of neurological damage, which varies markedly (Janke, 1994). Those who have looked at stroke and crash risk have mostly failed to find significant relationships between them (Gresset & Meyer, 1994b; Johansson et al., 1996; Koepsell, Wolf, & McCloskey, 1994). Sims et al. (2000), on the other hand, looked at the five-year prospective crash data of older drivers in the USA and found that crash involvement was more likely among drivers who reported having suffered a CVA or TIA prior to the commencement of the study.

Studies looking at the driving performance following a stroke are much more common. Unlike studies looking at crash involvement, studies into driving performance have typically produced negative findings regarding drivers who have suffered CVAs (Legh-Smith, Wade, & Hewer, 1986; Lundqvist, Gerdle, & Ronnberg, 2000; Quigley & DeLisa, 1983; Wilson & Smith, 1983).

Those who have suffered a number of strokes may develop multi-infarct dementia (widespread cognitive impairment resulting from repeated disruption of blood supply to parts of the brain, see Lezak, 1995), which leads to substantial decrements in driving ability (Fitten et al., 1995). The current Australian guidelines for assessment of fitness to drive (Austroads, 2001) require that those who have suffered a CVA do not drive for a minimum of one month post-event, with the return to driving dependent on the permission of physicians and, where appropriate, a driving assessor.

Although the varied nature of CVAs makes it difficult to make general statements about their relationship with driving ability, the literature is unequivocal regarding the tendency for drivers to cease driving following a stroke (Campbell et al., 1993; Eberhard, 1996; Forrest, Bunker, Songer, Coben, & Cauley, 1997; Freund & Szinovacz, 2002; Marottoli, Mendes de Leon et al., 1997; Persson, 1993; Stewart, Moore, & Marks, 1993). Factors related to cessation are discussed in section 4.3.4.

3.2.4 Cardiovascular Diseases

Medical conditions associated with the cardiovascular system that have been studied by road safety researchers have included angina, cardiac failure, arrhythmia, heart disease, hypertension and atherosclerosis (Fildes, 1997). Some studies have found increased crash rates for drivers with cardiovascular conditions (Gallo, Rebok, & Lesikar, 1999; McGwin Jr, Sims, Pulley, & Roseman, 2000; Medgyesi & Koch, 1995; Waller, 1965), while others have found the opposite (Johansson et al., 1996; Sims et al., 2000; Sims, Owsley, Allman, Ball, & Smoot, 1998; Vernon et al., 2002; Waller & Naughton, 1983). The latter findings could have been due to reductions in driving exposure for those with these conditions (Janke, 1994; Waller, 1992).

The current Australian guidelines for assessment of fitness to drive (Austroads, 2001) note that cardiovascular conditions tend to be progressive and so regular reviews of medical status are required. Varying periods of driving cessation are recommended for various cardiovascular events (acute myocardial infarct, acute episode of atrial fibrillation, cardiac arrest, episodes of deep vein thrombosis) and treatments (repair of aneurysms, angioplasty, insertion of cardiac defibrillator, insertion of pacemaker, cardiac surgery, treatment of heart block).

3.2.5 Diabetes Mellitus

Diabetes Mellitus is a condition that increases in prevalence with age (Fildes, 1997; Janke, 1994; Wallace & Retchin, 1992) and results in impaired control of glucose levels in the blood (Lezak, 1995). When glucose levels are too low (a state called "hypoglycaemia"), diabetics exhibit decreased co-ordination, impaired judgement, confusion and disorientation, and can suffer loss of consciousness (Ray, Gurwitz, Decker, & Kennedy, 1992). Ray et al. add that the risk of hypoglycaemia increases with age, while the adrenergic responses that alert diabetics to the need for carbohydrates decrease with age (Ray, Gurwitz et al., 1992). Waller (1992) and Cox, Gonder-Frederick and Clarke (1993) pointed out that even moderate hypoglycaemic states can lead to cognitive deficits that may affect driving without the driver being aware that they are impaired. Wallace and Retchin (1992) also noted that diabetes may be complicated by diabetic retinopathy (see section 3.2.1) and peripheral neuropathy. It can also lead to early onset of cataract and has been associated with glaucoma (Mitchell, 2003).

Most studies have found an increased crash risk among diabetic drivers (Daigneault et al., 2002a; Frier, Matthews, Steel, & Duncan, 1980; Hansotia & Broste, 1991; Koepsell et al., 1994; Ray, Gurwitz et al., 1992; Underwood, 1992; Vernon et al., 2002; Waller, 1992) but some studies have not shown such an effect (Janke, 1994; Sims et al., 2000; Sims et al., 1998). Very few studies have assessed the on-road driving performance of diabetic drivers. One study by Fitten et al. (1995) found that drivers with diabetes drove equally as well as healthy controls.

The Australian guidelines for assessment of fitness to drive indicate that driving should only be disallowed if diabetes is managed poorly or if there is poor compliance with treatment (Austroads, 2001). Also, drivers need to be cleared to continue driving by a physician after a major hypoglycaemic episode.

3.2.6 Arthritis

Another medical condition that increases in prevalence with age and that would be expected to affect driving is arthritis (Roberts & Roberts, 1993). Osteoarthritis has been found to increase in prevalence exponentially after the age of 50, affecting over 50% of those aged over 65, and is probably the most common cause of musculoskeletal disability among older persons (Janke, 1994; Waite et al., 2003).

There are many reasons why arthritis could be expected to have a negative effect on driving. By reducing strength and range of motion, arthritis could make it more difficult to steer and turn the head to scan for hazards. Reduced functioning of the hip and leg joints could reduce the ability to brake quickly when needed, and the pain caused by arthritis may be distracting and promote fatigue (Janke, 1994).

Although these factors may make arthritis hazardous to driving, relatively few studies have directly assessed the relationship between this condition and road crashes. With the exception of a Canadian study by Tuokko et al. (1995), which found an increased risk of crashing for people with arthritis, most studies have reported no relationship between the two (Foley et al., 1995; Sims et al., 2000; Sims et al., 1998; Stewart et al., 1993).

3.2.7 Parkinson's Disease

Parkinson's Disease is primarily a motor disorder, with a number of symptoms, including a "resting tremor" (a rhythmic shaking that diminishes with voluntary movement), muscular rigidity, difficulties initiating movement, and motor slowing (Lezak, 1995). Bondi and Troster (1997) report that its prevalence increases with age, with approximately 1% of those aged over 60 being affected, and that dementia is common among those with Parkinson's Disease, with 20 to 40% of those with the disease also exhibiting cognitive deterioration sufficient for a diagnosis of dementia.

Although there is some evidence that Parkinson's Disease may lead to compromised driving ability and greater crash involvement (Heikkila, Turkka, Korpelainen, Kallanranta, & Summala, 1998; McLay, 1989), it is more commonly reported that Parkinson's Disease leads to driving cessation (Campbell et al., 1993; Dellinger, Sehgal, Sleet, & Barrett-Connor, 2001; Eberhard, 1996; Freund & Szinovacz, 2002; Marottoli, Mendes de Leon et al., 1997; Stewart et al., 1993). Factors related to cessation are discussed in section 4.3.4 .

3.2.8 Seizure Disorders

Single seizures can result from a number of different conditions but recurring seizures lead to a diagnosis of epilepsy. Seizures involve excessive discharge of nerve cells in the brain, which leads to a variety of symptoms that feature disturbance of behaviour or perception (Lezak, 1995). The incidence of epilepsy has been found to increase after the age of 60 (Snyder & McConnell, 1997).

A condition that may involve a loss of consciousness and a gross interruption of motor functioning clearly poses a risk for safe driving. An epileptic seizure while driving would have a very high likelihood of leading to a crash. Studies of drivers diagnosed with epilepsy have tended to find that epilepsy is linked to an increased crash risk (Hansotia & Broste, 1991; Underwood, 1992; Vernon et al., 2002; Waller, 1992). Also, Hansotia and Broste (1993) found that drivers reporting a history of multiple seizures were more likely to be involved in injury crashes, while Taylor, Chadwick and Johnson (1996) found that an increased risk of crashes causing severe injury (fatal injury or injury resulting in hospital admission) was associated with the occurrence of seizures during the study period.

The Australian guidelines for fitness to drive (Austroads, 2001) specify that drivers who have been diagnosed with chronic epilepsy must be free of seizures for two years in order to qualify for a driver's licence. Drivers must also be free of seizures for varying specified periods of time if they: suffer an isolated seizure, have newly diagnosed epilepsy, have recurrent seizures due to identifiable sources of provocation (e.g. sleep deprivation, illness, drug interaction), have a seizure that causes a road crash, have seizures when asleep, are withdrawing from medication, or have surgery to treat epilepsy.

3.2.9 Mental Health

Problems related to ‘mental health’ encompass a broad range of conditions, including psychotic illnesses (e.g. schizophrenia), personality disorders, substance abuse (including alcoholism), and conditions characterised by negative mood (depression, anxiety disorders). A recent study by Vernon et al. (2002) found that drivers with ‘psychiatric illnesses’ (including all of the above, except for substance abuse problems) were more likely than age-matched controls to be involved in road crashes. However, few studies concerned with mental health and driving have been focussed on older drivers (Holland, Handley, & Feetam, 2003).

The most commonly studied mental health problem affecting older drivers is depression, which can be a considerable problem for older adults as it can accompany the bereavement, loneliness and ill-health that often occur in old age (Holland et al., 2003). Studies into crash involvement and depression among older adults have produced mixed results. Margolis, Kerani, McGovern, Songer, Cauley and Ensrud (2002) and Sims et al. (1998) both failed to find an association between depression and crash involvement among older drivers, using retrospective data. However, Sims et al. (2000) used prospective data for the same sample of drivers as Sims et al. (1998) and did find an association between depressed mood and greater crash involvement. Foley et al. (1995) used retrospective crash data and found a significantly greater crash risk for older drivers who were over the 80th percentile for depressive symptoms. One study has been conducted that examined the relationship between depression and on-road driving performance for different age groups and this study found no association between the two among drivers aged over 70 but did find one for drivers aged 18 to 44 (Garrity & Demick, 2001).

Depression is also known to be related to drink-driving behaviour (Beirness, 1993; Donovan & Marlatt, 1982), which, in turn, is well known to be related to an increased crash risk (e.g. McLean, Holubowycz, & Sandow, 1980). Holland et al. (2003) argue that the problem of alcoholism is underestimated among older adults, and add that it is especially common in widowers aged over 75.

With regard to anxiety, studies of its relationship with driving measures are rare (Holland et al., 2003) but Bierness (1993) reported that 'emotional instability', which could be associated with anxiety, has been linked to increased crash involvement. The driving performance study by Garrity and Demick (2001) found that anxiety, similarly to depression, was related to poorer driving performance only among young adults.

Of the other mental health problems, personality disorders associated with aggressive and impulsive behaviour have been reliably linked to crash involvement, especially for males. However, no studies of personality disorders and driving have been conducted that are focussed specifically on older drivers (Holland et al., 2003). Similarly, psychotic illnesses have been found to be related to an increased risk of crashing (e.g. Edlund, Conrad, & Morris, 1989) but have not been studied using samples of older drivers.

3.2.10 Medications

A factor related to the increase in medical conditions with age is the corresponding increase in the use of medications to treat these conditions. Ray et al. (1992), for example, reported that, in 1988 in the USA, those aged over 65 comprised 12% of the population but were responsible for 29% of prescription drug use. This has implications for road safety because many medications have side effects on the functioning of the central nervous system, which may be detrimental to driving ability. Also, there is a greater sensitivity with increasing age to anything that affects the central nervous system (Holland et al., 2003; Marottoli, 2002; Ray, Gurwitz et al., 1992), leading to an increased likelihood with age of adverse reactions to medication (Janke, 1994).

An increased crash risk has most commonly been associated with anti-depressants, especially older types of anti-depressants, (Hu, Trumble, Foley, & Eberhard, 1996; Leveille et al., 1994; Marottoli, 2002; Ray, Fought, & Decker, 1992). Increased risk of crash involvement has also been identified for drivers taking:

- benzodiazepines (Hemmelgram, Suissa, Huang, Boivin, & Pinard, 1997; Ray, Fought et al., 1992);
- analgesics (Johansson, Bryding, Dahl, Holmgren, & Viitanen, 1997; Leveille et al., 1994; Ray, Gurwitz et al., 1992);
- hypnotics (Sims et al., 2000);
- antipsychotics (Ray, Gurwitz et al., 1992);
- antihypertensives (McGwin Jr et al., 2000);
- non-steroidal anti-inflammatory drugs (Foley et al., 1995; McGwin Jr et al., 2000; Tuokko et al., 1995);
- anticoagulants (McGwin Jr et al., 2000);
- and hypoglycaemics (Ray, Gurwitz et al., 1992).

Older drivers, in addition to being more likely to take these medications, are also more likely to be taking more than one medication at a time, known as “polypharmacy” (Holland et al., 2003; Ray, Gurwitz et al., 1992; Stewart et al., 1993). Medications taken concurrently could have additive effects or, possibly, synergistic effects. That is, the different medications could react with each other to impair central nervous system functioning. However, there has yet to be a study showing such an effect. Foley et al.

(1995) reported recently, for example, that the number of different medications taken regularly by older drivers did not predict levels of crash involvement.

One counter-argument to claims that medication use among older drivers increases crash risk is that it may be that the crash risk of medicated drivers would be worse if the condition from which they suffered was not treated. Marottoli (2002, p9), for example, posed the question, "Would you prefer to have someone on antipsychotics behind the wheel or somebody who is psychotic behind the wheel?" It is also the case that links between medications and crash involvement may still be due to the condition being treated rather than the medication (Johansson, Bryding et al., 1997). Tuokko et al. (1995) found that drivers with arthritis who were taking non-steroidal anti-inflammatory medication had worse crash rates than those without arthritis and also those with arthritis not taking such medication. The authors, however, could not conclude that the increased risk was due to the effects of the anti-inflammatories because it was likely that those taking the medication were more severely affected by arthritis, possibly accounting for the increased crash risk.

Another counter-argument to the claimed negative effects of medication on driving is that there are methods by which the side effects of medication can be minimised. Marottoli (2002), for example, stated that the dosing schedule can be adjusted so that the medication is taken at times when it is least likely to affect driving. He added that patients can also be asked not to drive for a few days in the early stages of taking a new medication and can be allowed to resume driving gradually when it has been shown that the medication can be tolerated.

3.2.11 Summary and Conclusions

The preceding review has summarised a range of medical conditions and medications that have been found to adversely affect driving ability or to increase crash risk among older drivers. Links to either increased crash involvement, decreased driving performance, or both, have been established for cataract (e.g. Owsley et al., 1999), glaucoma (e.g. Wood, 2002b), dementia (e.g. Cooper et al., 1993b), cerebrovascular accidents (e.g. Sims et al., 2000), diabetes mellitus (e.g. Vernon et al., 2002), epilepsy (e.g. Hansotia & Broste, 1991) and various medications (anti-depressants, benzodiazepines, analgesics, antipsychotics, antihypertensives, non-steroidal anti-inflammatory drugs and hypoglycaemics) (e.g. Ray, Gurwitz et al., 1992). The findings for cardiovascular diseases, arthritis and depression, on the other hand, have been inconsistent, while the risks associated with diabetic retinopathy and psychiatric illnesses have not been determined. Macular degeneration and Parkinson's Disease have been linked more to cessation of driving than to an increased crash risk or decreased driving ability (e.g. Campbell et al., 1993).

It has been argued, however, that to find explanations for the increased crash risk of subsections of the older driver population, it is more appropriate to look at drivers' functional abilities rather than take an inventory of medical conditions with which they have been diagnosed (Marottoli et al., 1998; OECD, 2001; Sims et al., 1998; Wallace & Retchin, 1992; Waller, 1992; White & O'Neill, 2000). There are a number of reasons for this suggestion.

The first reason is that, among those with a specific medical diagnosis, there is substantial variation in the severity of the illness (Marottoli, 2002; Wallace & Retchin, 1992). In addition to different levels of severity, there can be marked differences across drivers in the progression of these conditions (Klavora & Heslegrave, 2002; Wallace & Retchin, 1992). There may also be different complication rates, clinical manifestations, and treatment response rates (Wallace & Retchin, 1992).

A second reason is that many older drivers have multiple medical conditions and it is the combination of different conditions that can impair functioning sufficiently to compromise driving ability (Dobbs, Heller, & Schopflocher, 1998; Klavora & Heslegrave, 2002; Marottoli, 2002; Wallace & Retchin, 1992; Waller, 1992). This may occur even when the manifestations of each of the separate conditions are minor (Marottoli, 2002).

The final reason is that these illnesses are superimposed on normal age-related changes in functioning. Two drivers with the same medical conditions at the same degree of severity may have very different levels of functional ability because one may have aged in other ways (non-pathological neuromuscular, cognitive, and perceptual declines) more than the other (Underwood, 1992; Wallace & Retchin, 1992; Waller, 1992).

Therefore, although medical conditions and medications can be linked to negative driving outcomes, it may be more useful to assess the functional abilities of drivers when trying to understand the increased crash risk of subgroups of the older driver population. The functional abilities necessary for driving include visual, physical, cognitive, and attentional abilities. The following sections (3.3-3.6) examine the relationship between these abilities and driving outcomes among older drivers.

3.3 Visual Functioning

Studies of the relationship between aging, driving, and functional abilities have regularly focussed on visual functioning. There are two main reasons for this. First, it has been claimed that over 90% of the sensory input necessary for driving performance is visual (Hills, 1980; Kline et al., 1992; Shinar & Schieber, 1991; Wood, 2002b). Secondly, there is a vast literature demonstrating declines with age in visual functioning (Cole, 2002; Wood, 2002a). The visual functioning abilities that have been reported to decline with age include static and dynamic visual acuity, contrast sensitivity, peripheral vision, resistance to glare, visual processing speed, visual search, low light sensitivity, perception of angular movement, movement in depth, colour vision, accommodation (adjusting focus to objects at different distances), and dot motion sensitivity (Fildes et al., 2000; Maycock, 1997; Wood, 2002a).

3.3.1 Visual Acuity

One of the most commonly tested abilities, not only in a research context but also in relation to driver licensure, is that of static visual acuity. This is the ability to discriminate fine, stationary, high contrast details (Bailey & Sheedy, 1988) and is typically assessed with wall charts, such as the Snellen chart, featuring high contrast letters of varying sizes that have to be correctly identified from a set distance. A person's visual acuity, determined on the basis of the smallest size of letter they are able to identify, is the distance at which they can resolve high contrast details compared to the distance at which the average person can resolve them.

The decline with age in static visual acuity has been well-established (Bailey & Sheedy, 1988; Cole, 2002; Haegerstrom-Portnoy, Schneck, & Brabyn, 1999; Hennessy, 1995; Klein, 1991; McConnell, Spall, Hirst, & Williams, 1991; Panek, Barrett, & Sterns, 1977; Wood, 2002a; Wood & Bullimore 1995). McConnell, Spall, Hirst, and Williams (1991), for example, reported the percentages of drivers in Australia with corrected visual acuity worse than that legally required to drive (6/12: able to read at 6m what the average person can read at 12m) to be approximately 5% for those aged 46 to 55, 10% for those aged 56 to 65 and over 15% for those aged 66 to 75. These percentages would underestimate population figures, due to exclusion of those who had been denied a driver's licence, or not applied for one, because of visual impairment.

The first large-scale studies designed to measure the relationship between visual functioning and crash rates were conducted by Burg (1964; 1967; 1968; 1971) and looked at the crash records of 17,500 drivers in the USA. These studies found a significant relationship between crash involvement and impaired visual acuity. A later re-analysis of Burg's data (Hills & Burg, 1977) was conducted with the sample broken up into four different age groups. This re-analysis found that there was no relationship between visual acuity and crash involvement for young and middle-aged drivers but that acuity did correlate with driving records for the group of drivers aged over 54.

This finding that there is a significant relationship between visual acuity and crash involvement has been repeated in other studies (Davison, 1985; Decina & Staplin, 1993; Hofstetter, 1976; Humphriss, 1987; Ivers, Boptom, & Cumming, 1999; Keltner & Johnson, 1987; Marottoli et al., 1998; Shinar, 1977; Sims et al., 1998; Vernon et al., 2002). Shinar (1977), for example, found that static visual acuity was related to daytime crash involvement for those aged over 54 and to crashes at all times of day for those over 64. Ivers et al. (1999), in an Australian study, found that self-reported crashes in the previous year were related to poorer acuity and especially to acuity of worse than 6/18 in the right eye. The authors suggested that the importance of the right eye was related to the need to detect objects of importance on the right side of the visual field in a jurisdiction in which motorists drive right-hand drive vehicles on the left-hand side of the road. As support for this interpretation, the authors cited a study conducted in England (Davison, 1985) that found similar results. Vernon et al. (2002) analysed the five year crash records of licensed drivers in the USA to determine the relative risks associated with a wide variety of self-reported medical conditions. It was found that poor visual acuity was one of the most common conditions and was associated with a significantly increased risk of crashing.

Although these studies found significant relationships between acuity and crashes, the size of these relationships has been small (Ball & Owsley, 1991; Decina & Staplin, 1993; Kline et al., 1992; Shinar & Schieber, 1991; Wood, 2002b). For example, in Hills and Burg's (1977) re-analysis of Burg's (1967) original data, it was found that less than one percent of variance in crash rates could be accounted for by changes in vision, even in the older group of drivers.

There are also studies that have failed to find any relationship between visual acuity and crashes (Gresset & Meyer, 1994a; Hennessy, 1995; Johansson et al., 1996; McCloskey, Keopsell, Wolf, & Buchner, 1994; Owsley et al., 1998; Sims et al., 2000). McCloskey et al. (1994), for example, failed to find that drivers over the age of 65 who had been involved in a crash in a two year period had lower acuity scores than age and sex-matched controls who were crash free. The authors suspected that part of the reason for the lack of an effect for acuity was that those with poor acuity tend to be removed from the driving population either through driver licensing-related screening procedures (e.g. the requirements for a medical certificate for licence renewal) or voluntary cessation. Hennessy (1995), in a study of drivers of varying age groups, did not find a significant relationship between visual acuity and three year crash involvement, either for all drivers or for drivers in specific age groups.

A number of studies have been conducted to assess whether visual acuity is related to on-road driving performance and most have failed to find a significant relationship (Carr, Jackson, Madden, & Cohen, 1992; Hunt et al., 1993; Janke, 2001; Schlag, 1993; Staplin, Gish, Decina, Lococo, & McKnight, 1998b). Hunt et al. (1993), for example, found no relationship between visual acuity and performance on a one hour driving test for a group of older drivers, including some with mild or very mild dementia. Carr et al. (1992) looked at the performance of three different age groups, including one aged over 65, on an on-road driving test and found that older drivers had far worse visual acuity but produced less errors on the road test compared with younger drivers. Schlag (1993) found differences between drivers aged over 60 and drivers aged 40 to 50 on tests of visual acuity but found few differences in levels of safety on a driving test conducted on public roads.

3.3.2 Contrast sensitivity

Aging is also associated with declines in contrast sensitivity (Brown, Greany, Mitchell, & Lee, 1993; Evans & Ginsburg, 1985; Haegerstrom-Portnoy et al., 1999; Hennessy, 1995; Klein, 1991; Owsley, Sekuler, & Siemsen, 1983; Schieber, 1988; Wood, 2002a; Wood & Bullimore 1995). Contrast sensitivity is the ability to perceive objects of differing luminance to the background. It varies as a function of spatial frequency (size of the objects to be detected) and luminance levels. Schieber (1988) reported that contrast sensitivity in the high and middle spatial frequency range declines with age especially after age 40. Decina and Staplin (1993, p267) claimed contrast sensitivity tasks are the "most representative of the full range of targets a driver must detect in the highway environment, particularly under twilight or night-time conditions." A standard measure of contrast sensitivity is the Pelli Robson Contrast Sensitivity chart (Pelli, Robson, & Wilkins, 1988), which requires the identification of high spatial frequency letters that gradually decrease in contrast against a white background.

Contrast sensitivity has been found to be related to older driver crash involvement (Brabyn, Schneck, Haegerstrom-Portnoy, & Steinman, 1994; Brown et al., 1993; Decina & Staplin, 1993; Hennessy, 1995; Ivers et al., 1999; Janke, 1994; Marottoli et al., 1998). For example, Brown et al. (1993) found, in a study of drivers over the age of 50, that contrast sensitivity declined with age and was the most discriminating visual measure for predicting crashes. Decina and Staplin (1993) analysed crash records and visual examinations of 12,400 drivers and found that mileage-adjusted crash risk was elevated among older drivers with poor visual acuity and visual fields, and this increased crash risk was worse for those who exhibited poor performance on a test of contrast sensitivity. The authors concluded that the older drivers most at risk of crashing are those who pass the vision standards for visual acuity and visual fields but who have poor contrast sensitivity. They argued that contrast sensitivity should be added to vision screening assessments used for driving licensure renewal. In Australia, Ivers et al (1999) found similar results for contrast sensitivity as for visual acuity, with worse sensitivity in the right eye being related to increased crash involvement.

In studies looking at on-road driving performance, Wood (2002a) found contrast sensitivity made a significant contribution to performance on a closed road driving test, while Janke and Eberhard (1998) found that contrast sensitivity was useful for differentiating between drivers referred for an assessment and a volunteer group.

Contrast sensitivity has also been found to mediate the relationship between cataract and elevated crash involvement (Owsley, Stalvey, Wells, Sloane, & McGwin Jr, 2001), and improvements in driving outcome measures after cataract surgery have been found to parallel improvements in contrast sensitivity (Wood, 2002b). Evans and Ginsburg (1985) found on a sign discrimination task using a projection film that older drivers exhibited shorter sign recognition distances than younger drivers matched for visual acuity, and that these differences were related to contrast sensitivity.

3.3.3 Visual field

The size of a driver's visual field is also known to decline with age (Johnson & Keltner, 1983; Klein, 1991; Panek et al., 1977; Talbot & Perkins, 1998; Wood, 2002a), leading to problems with peripheral vision (Maycock, 1997). Johnson and Keltner (1983) measured the visual fields of 10,000 driver's licence applicants and found that the prevalence of visual field loss was in the range of 3 to 3.5% for those aged under 60, 7% for those aged 61 to 65, and 13% for those aged over 65.

The size of a driver's visual field has been shown to be related to crash involvement. Johnson and Keltner (1983), for example, found that drivers with bilateral field defects (visual field loss in both eyes) had crash and conviction rates that were twice those of drivers with normal visual fields, and this increased to four times the rate for drivers aged over 65. Decina and Staplin (1993) found that visual field, in addition to visual acuity and contrast sensitivity, was related to crash involvement among those aged over 65. Hennessy (1995), in his study of drivers in the USA, found a small correlation between visual field deficits and crash involvement in the past three years among those aged over 70. There was also a significant relationship between visual fields and crash involvement for this age group, once age, gender, exposure, and self-restriction of left turns were controlled statistically.

Decrements in driving performance in both a simulator (Lovsund, Hedin, & Tornros, 1991) and on public roads (Tarawneh, McCoy, Bishu, & Ballard, 1993) has also been related to visual field loss. Visual field deficits simulated with specially designed goggles have also been found to correlate significantly with driving performance on a closed road circuit but not as strongly as simulated cataracts (Wood & Troutbeck, 1994, 1995).

Other studies have failed to find a relationship between crashes and diminished visual fields (Burg, 1967, 1968; Ivers et al., 1999; Marottoli et al., 1998; Shinar, 1977). For example, the study by Ivers et al (1999) of drivers in New South Wales, Australia found significant relationships with self-reported crash involvement for visual acuity and contrast sensitivity but not for visual fields.

3.3.4 Other Visual Abilities

Although the visual abilities most researched with regard to older drivers have been visual acuity, contrast sensitivity and visual fields, other aspects of vision necessary for driving have also been considered. One such ability that is important for driving and that declines with age is the perception of movement in depth (Fildes et al., 2000; Klein, 1991; Staplin et al., 1998a). The effects of problems with movement perception were demonstrated in a study by Scialfa, Guzy, Leibowitz, Garvey, and Tyrrell (1991). In this study, it was found that older drivers accepted smaller gaps for turning movements at intersections because they based their decisions on the distance to the approaching vehicle, while younger drivers based their decisions on the time gap separating themselves from the approaching vehicle, taking into account both the speed of the vehicle and its distance from them. This meant that older drivers would accept smaller time gaps than younger drivers when the approaching vehicle was travelling at high speed. A study of the on-road driving performance of older drivers by Tarawneh, McCoy, Bishu and Ballard (1993) found that sensitivity of depth perception was related to performance at controlled intersections (i.e. intersections controlled by either traffic signals or signs).

Another visual ability that declines with age is the ability to resist the effects of, and recover from, glare (Haegerstrom-Portnoy et al., 1999; Klavora & Heslegrave, 2002; Klein, 1991; OECD, 1985; Olson, 1988; Olson & Sivak, 1984; Pulling, Wolf, Sturgis, Vaillancourt, & Dolliver, 1980; Shinar & Schieber, 1991; Wood, 2002a). A loss in the ability to resist the effects of glare makes it difficult for older drivers to cope with oncoming headlights at night and exacerbates the difficulties caused by declines in contrast sensitivity (Staplin et al., 1998a). For example, Staplin, Lococo, and Sim (1992) found that detection of road curvature ahead at night was especially difficult for older drivers in the presence of glare. Shinar and Schieber (1991) also reported that older drivers experience fatigue after prolonged exposure to headlights at night.

3.3.5 Summary

In summary, visual functions have been related to both crash involvement and driving performance, with the visual abilities most often studied being visual acuity, contrast sensitivity, and visual fields. Measures of these three aspects of vision were therefore included as potential predictors of the driving performance of older drivers in the present study.

Some authors, however, have pointed out that the relationships between visual abilities and driving measures have been small, and have argued that simple visual tests are not sufficient to account for performance differences on the complex task of driving. Schieber (1988) claimed that visual acuity, for example, is a measure of vision in ideal circumstances that does not permit generalisation to the dynamic environment of driving. Similarly, Ball and Owsley (1991) pointed out that simple visual tests, such as tests of visual acuity and visual fields, are appropriate for the clinical assessment of vision loss but do not reflect the visual complexity of the driving task. When driving, they argued, motorists must respond to a cluttered visual array, cope with primary and secondary tasks, and simultaneously utilise central and peripheral vision. They added that there is also uncertainty regarding when and where important visual stimuli will occur. Stokes (as cited in Simoes & Marin-Lamellet, 2002) suggested that declines with age in the ability to detect, interpret, and respond to visual stimuli in the road environment may be due to slowing of information processing more than declines in simple sensory abilities. It has also been pointed out that if drivers' cognitive abilities are sound, they may be able to use compensatory strategies to accommodate decrements in vision (Klavora & Heslegrave, 2002; Kline et al., 1992). Maycock (1997) concluded that, for studies of aging and driving, it was necessary to assess visual measures combined with cognitive processing. One measure combining visual abilities and cognitive processing is visual attention. Studies relating to older drivers and attention are described in the following section.

3.4 Attention

An aspect of cognitive functioning that declines with age and has often been implicated in older driver crashes is visual attention. Attention may be defined as a mechanism used to prepare for processing of stimuli, to focus on the stimuli to be processed, and to determine the extent of the processing. It may also be defined as the capacity or energy available for cognitive processing (McDowd & Birren, 1990). It is commonly identified as a capacity that declines with age (Madden, 1990; Staplin et al., 1998a; Wright, 1981) and has been claimed to underlie declines in overall cognitive processing among the elderly (Craik & McDowd, 1987; Craik & Simon, 1980; Hasher & Zacks, 1979; Stankov, 1988). Attentional declines are thought to contribute to the increased crash involvement of older drivers (Brouwer, Waterink, Van Wolffelaar, & Rothengatter, 1991; Parasuraman & Nestor, 1991; Transportation Research Board, 1988), especially at intersections (Ball & Owsley, 1991; De Raedt & Ponjaert-Kristoffersen, 2001; Hakamies-Blomqvist, 1993; Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson, 1998; Preusser et al., 1998; Rizzo et al., 2001; Staplin et al., 1998b). According to McDowd and Craik (1990), there are four different types of attention: sustained, switching, selective and divided.

3.4.1 Sustained Attention

Broadly speaking, sustained attention, or “vigilance”, refers to the ability to maintain performance over extended periods of time (McDowd & Craik, 1988). Parasuraman and Nestor (1991) defined sustained attention in more narrow terms, describing it as the ability to detect infrequent or unpredictable events, especially after a prolonged period of observation. With driving, vigilance must be maintained over long journeys in order to detect hazards that occur infrequently (Lundberg et al., 1997; Maycock, 1997). Studies of target detection over prolonged periods of driving have found declining performance with increased time spent on the road (Naantanen & Summala, 1976; Sanders, Wildervanck & Gaillard, as cited in Parasuraman & Nestor, 1991).

Studies of sustained attention and age have produced mixed results (McDowd & Birren, 1990), with poorer overall test performance by older adults but little evidence for a greater rate of decline in performance over time (Giambra & Quilter, 1985). Poorer performance on tests of sustained attention has been reported for those with DAT (Lundberg et al., 1997; Parasuraman & Nestor, 1991; Rizzo et al., 2001).

In terms of predicting road safety outcomes, tests of sustained attention have not been linked with crash involvement (Parasuraman & Nestor, 1991), whereas findings have been mixed for on-road driving performance. Duchek et al. (1998) and Cushman (1996) both studied sustained attention and on-road driving performance among samples of older drivers including those diagnosed with DAT. Despite using similar tasks for measuring sustained attention, Cushman found that sustained attention was predictive of driving performance while Duchek et al. did not. A study looking at driving simulator performance by those with and without DAT found that, although those with DAT had poorer sustained attention and were more likely to crash at intersections on the simulator, sustained attention was not predictive of crashes (Rizzo et al., 2001). Parasuraman and Nestor (1991) concluded that sustained attention was more an issue for professional drivers who drive long distances than for the typical older driver.

3.4.2 Switching Attention

Switching attention is defined by McDowd and Birren (1990) as alternately monitoring two or more sources of input, while others, such as Parasuraman and Nestor (1991), view switching attention as a facet of selective attention (see section 3.4.3.). For the purposes of this review, switching attention will be treated as a separate aspect of attention, as described by McDowd and Birren.

A number of recent studies in the USA have included visual measures of switching attention in test batteries used to predict on-road driving performance (Hunt et al., 1993; Janke, 2001). Hunt et al. (1993) used a pen and paper test requiring participants to switch between circling numbers and circling letters. Performance on this test correlated with on-road driving performance among a sample of healthy older adults and those with either mild or very mild dementia. Janke (2001) assessed a sample of drivers aged over 65, including healthy volunteers and those referred for a licence assessment, with a battery of tests, including a Cue Recognition test that combined selective and switching attention. It was found that poor performance on this test predicted errors on an on-road test better than any other test in the battery. In a follow-up study by the same author of a sample of healthy volunteers aged 70 or more, Cue Recognition did not make a significant contribution to prediction of driving performance, although this may be due to the homogeneity of the healthy, high-functioning sample (Janke, 2001).

3.4.3 Selective Attention

Selective attention refers to the ability to filter out irrelevant information and focus on information needed for processing (McDowd & Birren, 1990). When driving, it is necessary to focus attention on salient events in a complex visual environment that features moving and distracting stimuli (Lundberg et al., 1997; Staplin et al., 1998a), and so it can be expected, on *a priori* grounds, that selective attention would be related to driving.

Studies into aging and road safety have regularly found that selective attention is related to crash involvement (Daigneault et al., 2002a; Lundberg et al., 1998; Marottoli et al., 1998; Stutts, Stewart, & Martell, 1998) and driving performance (Clark et al., 2000; Cushman, 1996; De Raedt & Ponjaert-Kristoffersen, 2000; Duchek et al., 1998; Janke, 2001; Lundqvist et al., 2000; Odenheimer et al., 1994; Richardson & Marottoli, 2003). Selective attention has also been found to be related to intersection crashes on a driving simulator (Rizzo et al., 2001). Daigneault et al. (2002a), for example, looked at crash involvement among drivers aged over 65 and found that performance on the Stroop Colour Word Tests was significantly worse among drivers who had been involved in three or more crashes in the previous five years, compared to drivers with crash-free records who were matched for age and driving exposure. Duchek et al. (1998) found driving performance among a group of older drivers, including some with mild or very mild DAT, was related to performance on a visual search (selective attention) test and false alarms on a visual monitoring (sustained attention) test. The authors argued that the false alarms on the sustained attention test were the result of poor inhibitory control and actually represented a selective attention component of the task. They concluded that selective attention predicts driving performance above and beyond cognitive status and psychometric measures (Duchek et al., 1998).

A test that measures selective attention and that has been used in a number of older driver studies is the Useful Field of View test (UFOV: Owsley et al., 1998). The UFOV test is a computer-based visual processing measure assessing speed of information processing, and selective and divided attention. In the first module of this test (Perceptual Response Time), participants must discriminate between two targets presented centrally for very brief durations (40 to 240 milliseconds). In the second module (Divided Attention), participants must perform the Perceptual Response Time component and, additionally, identify the radial direction of a target presented up to 30 degrees in the periphery. In the final module (Selective Attention), the same tasks as those in the second module are performed but with the peripheral targets embedded in visual distracters. The different components allow for three different sets of scores in addition to an overall composite score (Owsley et al., 1998).

A number of studies have found that the UFOV test is related to crash involvement (Ball & Owsley, 1991; De Raedt & Ponjaert-Kristoffersen, 2001; Owsley et al., 1998; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Sims et al., 2000; Sims et al., 1998) and on-road driving performance (Cushman, 1996; De Raedt & Ponjaert-Kristoffersen, 2000). Studies of drivers aged 55 or more in the USA, using both retrospective (Sims et al., 1998) and prospective police-reported crash data (Sims et al., 2000), found a heightened risk of crash involvement for those with impaired performance on the UFOV test. Cushman's (1996) study of older drivers in the USA found that results on the UFOV test, particularly for the selective attention module, were associated with driving test scores more strongly than other cognitive and attentional measures.

The relationship between UFOV test performance and crashes has been found to be stronger when particular types of crashes are analysed. De Raedt and Ponjaert-Kristoffersen (2001) looked at self-reported crashes in a twelve month period for drivers referred for a driving fitness evaluation in Belgium. It was found that UFOV performance was significantly related to collisions, when travelling straight ahead, with vehicles that were approaching from the right and had the right of way. Similarly, Ball and Owsley (1991) found UFOV performance predicted intersection crashes better than other crashes among drivers aged over 55.

However, there have also been studies that have not replicated the associations between UFOV and crash involvement. In a large-scale study of insurance policy holders aged over 50, UFOV performance was not significantly correlated with crash involvement (Brown et al., 1993). Hennessy (1995) also found that UFOV performance was not significantly associated with the three-year crash involvement of a large sample of drivers. When the analysis was restricted to drivers aged over 70, UFOV accounted for only 4% of crash variance.

3.4.4 Divided Attention

Divided attention is the process by which attention is controlled in order to perform two simultaneous tasks, and has been reliably demonstrated to decline with age (McDowd & Birren, 1990). Craik (1977, p391) wrote that "one of the clearest results in the experimental psychology of aging is the finding that older adults are more penalised when they must divide their attention." Even when the difficulty of individual tasks has been adjusted to match the abilities of individual participants, dual task experiments have still produced age-related decrements in performance (Brouwer et al., 1991; Ponds, Brouwer, & Van Wolffelaar, 1988).

Many authors have highlighted the importance of divided attention for driving on theoretical grounds (Charlton, Oxley, Fildes, & Les, 2001; De Raedt & Ponjaert-Kristoffersen, 2001; de Waard, van der Hulst, Hoedemaeker, & Brookhuis, 1999; Hakamies-Blomqvist, 1993; Lundberg et al., 1997; Lundqvist et al., 2000; Parasuraman & Nestor, 1991; Preusser et al., 1998; Staplin et al., 1998a). Parasuraman and Nestor (1991), for example, claimed that driving is a good real world example of a divided attention task. While driving, one must co-ordinate several tasks, even when driving in routine, low traffic conditions. A large amount of driving practice leads to some tasks becoming automatic and, therefore, requiring few attentional resources. This means that divided attention demands may be low in many conditions. However, in dense traffic or at intersections and roundabouts, demands on divided attention may exceed some drivers' capabilities (Parasuraman & Nestor, 1991). Staplin et al. (1998a) noted that when driving, it is necessary to balance the allocation of attentional resources between tasks such as lane selection and path maintenance, and tasks related to detection of, and response to, potential conflicts with other traffic and pedestrians.

Although the theory relating divided attention to driving is convincing, empirical studies linking the two are not as numerous as those linking driving to indices of selective attention, possibly because there is a paucity of standardised measures of divided attention. Most researchers assessing divided attention develop their own dual task procedures. In a study of self-reported crash involvement of drivers aged over 64 who were referred for a driving assessment, De Raedt and Ponjaert-Kristoffersen (2001) found that a test of divided attention, which required simultaneous performance of tracking and visual scanning tasks, predicted the incidence of at-fault crashes when parking. The authors explained this finding by saying that parking manoeuvres require steering control while being simultaneously engaged in visual scanning tasks. These participants also completed an on-road driving test, with divided attention being significantly related to driving performance (De Raedt & Ponjaert-Kristoffersen, 2000). Owsley et al. (1998) looked at the three-year crash involvement of adults aged over 54, and found that a measure of divided attention taken from the UFOV test (discussed in section 3.4.3) was a significant predictor of crashes, after adjusting for age, race, gender, medical conditions, mental status, and days driven per week.

3.4.5 Summary

Many studies have looked at the relationship between sustained, switching, selective and divided attention, and the crash involvement or on-road driving performance of older drivers. While sustained attention has not been shown to be related to driving outcomes among older drivers (e.g. Duchek et al., 1998), the other forms of attention, particularly selective attention, have often been found to decline with age and to be associated with both the crash involvement (e.g. De Raedt & Ponjaert-Kristoffersen,

2001) and driving performance of older drivers (e.g. Cushman, 1996). For this reason, a measure of divided and selective visual attention was designed specifically for the present study investigating predictors of the on-road driving performance of older drivers.

Attention is only one of a number of cognitive abilities that are thought to be necessary for competent driving. The following section provides a summary of some other aspects of cognitive functioning and the extent to which they have been found to be related to crash incidence and reduced driving ability in older drivers.

3.5 Other Cognitive Abilities

Many theorists have stated that a variety of cognitive abilities, in addition to attention, are essential for the safe operation of a motor vehicle. These theories are largely based on the information processing model pioneered by Broadbent (1958) and view driving as a task that requires ongoing processing of multiple environmental stimuli, and the use of memory processes and judgement for rapid decision making (Ball & Owsley, 1991; Rizzo et al., 2001; Stalvey & Owsley, 2000; Transportation Research Board, 1988; Underwood, 1992). The finding that certain cognitive abilities decline with age has prompted some authors to postulate that this decline plays a role in the crashes of older drivers, especially those occurring in complex situations, such as at intersections (Adler, Rottunda, & Kuskowski, 1999; Cooper, 1990a; De Raedt & Ponjaert-Kristoffersen, 2001; Lundberg et al., 1998; Maycock, 1997; Regan, Oxley, Godley, & Tingvall, 2001; Rizzo et al., 2001; Staplin et al., 1998a). The cognitive abilities that are known to decline with age and that have been investigated with regard to the crashes and driving ability of older drivers include the following: overall cognitive or mental status, visuospatial and constructional abilities, memory, and speed of information processing.

3.5.1 Mental Status

Mental status refers to a person's level of basic cognitive functioning and awareness, and is impaired by dementing conditions. There are a number of screening tests for dementia that assess mental status but the most widely used is the Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). This test provides a very quick measure of a number of domains (orientation, registration, attention, language, construction) that comprise basic cognitive functioning, with cut-off scores indicative of cognitive impairment having been determined for different age groups and levels of education (Lezak, 1995).

Generally, studies have indicated that mental status is related to crash involvement and driving ability (Ball & Owsley, 1991; Clark et al., 2000; Cushman, 1996; Fitten et al., 1995; Johansson et al., 1996; Marottoli, Cooney Jr, Wagner, Douchette, & Tinetti, 1994; Odenheimer, 1993; Rizzo et al., 2001; Sims et al., 1998). However, a number of studies have failed to find significant associations between mental status and driving-related outcome measures (Janke, 2001; Lesikar, Gallo, Rebok, & Keyl, 2002; Sims et al., 2000). Lesikar et al. (2002) attributed their finding to some of the abilities measured by the MMSE (e.g. verbal memory) not being important for driving. In this study, the authors attempted to predict only ten crashes among 72 drivers, with none of their functional measures being related to crash involvement. Janke (2001), on the other hand, described the sample in her study as homogenous and attributed the failure of the MMSE to predict driving outcomes as being due to a limited range of MMSE scores, with the mean score for the sample being approximately 29 out of 30 (SD = 1.6).

It has been argued that the use of the MMSE in studies designed to explain the increased risk of crashes among older drivers, and, more particularly, to identify drivers with an increased risk, is of little value (Lundberg et al., 1997). This is because tests like the MMSE are routinely used to aid the diagnosis of dementia. These authors argued that claiming drivers with low MMSE scores are at risk for crashing says nothing over and above the well-established finding (see section 3.2.2.) that drivers with dementia exhibit increased crash risk. Hakamies-Blomqvist and Peters (2000) added that, if the aim is to identify drivers with early signs of dementia, this is best left to the medical fraternity. For this reason, researchers have started to control for mental status prior to completing analyses designed to predict the crash involvement or driving performance of older drivers using other functional measures (Clark et al., 2000; Duchek et al., 1998; Owsley et al., 1998; Owsley et al., 1999).

3.5.2 Visuospatial and Constructional Abilities

One of the tasks in the MMSE is a visuospatial and constructional task that requires test takers to copy a drawing of intersecting polygons. This task has been identified by Teng, Chui, Schneider, and Metzger (1987) as the second most difficult task in the MMSE, behind the three word recall task. Marottoli, Cooney Jr, Wagner, Douchette, and Tinetti (1994) found that the intersecting polygon copy item on the MMSE was, by itself, significantly associated with adverse driving events (crashes and violations) among drivers aged over 71.

This finding is consistent with other studies finding significant relationships between on-road driving performance measures and other measures of visuospatial and construction abilities among samples of older drivers. Significant relationships with driving performance have been found for the Rey-Osterrieth Figure Copy Test (Clark et al., 2000; Rizzo et al., 2001); the Block Design subtest of the Wechsler Adult Intelligence Scale, third edition (Clark et al., 2000; Lundberg et al., 1998; Rizzo et al., 2001); the Benton Copy Test (Hunt et al., 1993); and a task requiring participants to copy a drawing of a cube (Johansson et al., 1996).

3.5.3 Memory

Another cognitive ability studied by researchers investigating older drivers is that of memory. Memory could be expected to be associated with driving outcomes, as memory decline is a major symptom of DAT, which, in turn (see section 3.2.2), has been associated with greater crash involvement (Fildes, 1997; Foley et al., 1995; Lundberg et al., 1997). However, a number of authors have also justified the study of memory on theoretical grounds. One aspect of memory that declines with age and that is thought to be important for the negotiation of intersections is "working memory", which involves the mental manipulation of information that is being held in short term memory (De Raedt & Ponjaert-Kristoffersen, 2000, 2001; Simoes & Marin-Lamellet, 2002; Staplin et al., 1998a). Ball and Owsley (1991) pointed out that memory is also needed for navigation purposes and Lundberg et al. (1997) claimed that, if an older driver gets lost, they are more likely to start making potentially hazardous driving errors.

Studies into memory have demonstrated the role of visuospatial memory in driving outcomes for older drivers. De Raedt and Ponjaert-Kristoffersen (2000; 2001) used a computer-administered paper-folding task to assess visuospatial abilities with a working memory component in drivers aged over 64. They found that visuospatial memory was significantly associated with both on-road driving performance and involvement in collisions at intersections, either with vehicles approaching at 90 degrees with the right of way, or when attempting to turn across oncoming traffic. The authors explained this by saying that turns across traffic, or driving across intersections when vehicles travelling at 90 degrees have the right of way, requires making judgements based on prior information. "Information on former situations must be retained in working memory in order to make predictions about the time to arrival of oncoming traffic" (De Raedt & Ponjaert-Kristoffersen, 2001, p817). Lundberg et al.

(1998) found that a sample of crash-involved drivers aged over 65 exhibited significantly poorer performance on the Rey Figure recall test of visuospatial memory than non-crash-involved drivers of similar age. The crash-involved drivers were also worse at a test of verbal episodic memory, which the authors attributed to the early effects of dementia. Richardson and Marottoli (2003) found that the Visual Reproduction subtest of the Wechsler Memory Scale - Revised was related to on-road driving performance among older drivers in the USA.

Studies of other aspects of memory and driving outcomes for older drivers have produced mixed results. Foley et al. (1995) looked at the five year crash involvement of drivers aged over 67 and found that increased crash involvement was associated with poorer verbal memory. Like Lundberg et al (1998), the authors attributed this finding to poorer verbal memory being an early sign of dementia. However, Clark et al. (2000) analysed the on-road driving performance of drivers with dementia and found that, whilst attentional, constructional and premorbid abilities were significantly associated with driving performance after controlling for mental status, memory performance (verbal and working memory) was not.

3.5.4 Speed of Information Processing

The rate at which information is processed is known to decrease markedly with age (Birren & Fisher, 1995; Cerella, 1985; Salthouse, 1985). The finding of poorer performance by older adults on tasks measuring speed of information processing has been reported so widely that Salthouse (1985) described it as the most robust finding in the gerontological literature. Speed of information processing is thought to be an important ability for driving because drivers must respond to complex stimuli under time pressure (Charlton et al., 2001; de Waard et al., 1999; Fildes, Lee, Kenny, & Foddy, 1994; Klavora & Heslegrave, 2002; Maycock, 1997; Staplin et al., 1998a).

One measure of speed of information processing that is expected to be related to driving on *a priori* grounds is reaction time. A short reaction time would be a great advantage to drivers who must respond to an emergency situation. Simple reaction time is well known to decline with age (Salthouse, 1985) and larger age differences are found with each additional choice in choice reaction time tasks (Cerella, 1985). It has also been found that older adults take longer for all components of decision making, including acquiring and processing information, and selecting, planning and executing responses (Fildes, Lee et al., 1994).

However, studies examining the relationship between reaction times of older drivers and crashes or on-road driving performance have proved disappointing. Lundberg et al. (1998) found that slower reaction time was not significantly related to crash involvement for drivers aged over 65. Marottoli et al. (1998) failed to find a significant association between reaction time measures and adverse events (crashes or convictions for traffic offences) in a five year period among drivers aged over 76. Carr et al. (1992) found that a sample of healthy older drivers (aged over 68) performed more poorly on reaction time tests than younger drivers (aged 18-35) but equally well on an on-road test. The authors explained this by saying that on-road tests do not measure reactions to the sort of emergency situations in which reaction time performance would be crucial. Ranney (1994) claimed that the lack of a strong association between reaction time and driving outcome measures was due to older drivers being able to compensate for these deficits, presumably by driving more slowly.

Despite these findings, it may still be the case that declining speed of information processing is an important factor in older driver crashes. It is possible that age-related declines in a number of cognitive domains are the result of slowed information processing (Salthouse, 1985) and that the effects of attention and cognition on driving outcome measures represent the indirect effects of slowed processing.

Lundqvist et al. (2000), for example, found that poor driving performance among older drivers (aged over 60) who had a suffered stroke was associated with decrements in attentional and cognitive processing, which, in turn, were due to slowed information processing. In addition, the UFOV test, which has been found to be associated with older driver crashes in a number of studies (see section 3.4.3.), requires a fast rate of information processing for each of its modules, as the stimuli are presented for very short durations (Owsley et al., 1998). In fact, the first module of the UFOV test (Perceptual Response Time) is a measure of speed of information processing, and has been found to be a significant predictor of the on-road driving performance of older drivers (Janke, 2001).

It is also possible that speed of information processing is not a unitary construct, as different speed measures have been found to have low correlations with each other (Salthouse, 1985). Nettelbeck and Rabbitt (1992) found that different measures of speed of information processing made independent contributions to measures of cognitive performance in older adults. It could be that different measures of speed of information processing may also make independent contributions to driving outcome measures.

3.5.5 Summary

Cognitive factors, in addition to attentional abilities, have been found to play a major role in the crash involvement and driving performance of older drivers. The cognitive factors most clearly associated with older driver problems are overall mental status (e.g. Ball & Owsley, 1991), visuospatial functioning (e.g. Clark et al., 2000) and memory functioning (especially visuospatial working memory) (e.g. De Raedt & Ponjaert-Kristoffersen, 2000). The evidence also suggests that age-related decrements in speed of information processing (e.g. Lundqvist et al., 2000) contribute to negative driving outcome measures for older drivers. Given these previous findings, measures of mental status, visuospatial memory and speed of information processing were included in the present study as potential predictors of the driving performance of older drivers.

3.6 Physical or Motor Functioning

There are a number of physical changes that occur with age that may be detrimental to driving ability (Fildes, Lee et al., 1994; Maycock, 1997; Staplin et al., 1998a). With increasing age, there are reductions in muscle mass and flexibility, in bone mass, in joint flexibility, and in central and peripheral nerve fibres. These physical changes occur among the healthy aged and can also be produced by disease processes, such as the decreased joint flexibility caused by arthritis (see section 3.2.6.) (Fildes, Lee et al., 1994; Maycock, 1997; Staplin et al., 1998a). The resulting changes in motor functioning potentially detrimental to driving include reduced strength and flexibility in the arms and shoulders, reduced ability for head and neck rotation, and reduced hip and leg strength.

Drivers need strength in their arms and shoulders mainly for steering but also for changing gears in automobiles fitted with manual transmissions (Fildes, 1997). However, there is no evidence for a relationship between the physical strength of older drivers and either crash involvement or driving performance. Studies of older drivers have failed to find a relationship between hand grip strength and crash involvement, using either retrospective (Marottoli et al., 1998; Sims et al., 1998) or prospective (Sims et al., 2000) crash data. With regard to on-road driving performance, neither Hunt et al. (1993) nor Odenheimer et al. (1994) found relationships between measures of physical strength and performance on practical driving assessments by older drivers. Fildes (1997) and Roberts and Roberts (1993) noted that declines in arm strength can be accommodated to some degree by driving cars with power steering and automatic transmissions.

Flexibility of movement also declines with age, and of particular importance for driving is restricted head and neck movement (Evans, 1991a; Fildes, 1997; Maycock, 1997; Staplin et al., 1998a), which is needed to scan visually for hazards (Janke, 1994), particularly at intersections (Staplin et al., 1998a). Studies into flexibility have produced more significant results than those of strength, with Marottoli et al. (1998) finding a relationship between head and neck rotation and adverse driving events (crashes or convictions). Similarly, McPherson, Ostrow, Shaffron, and Yeater (1988) found that reduced joint flexibility and restricted range of motion in the upper body were associated with poorer on-road driving performance among older drivers.

Not all studies assessing head and neck rotation and driving performance have revealed significant relationships between the two. Staplin et al. (1998b) found that the degree of head rotation was not associated with driving performance among drivers aged over 60 who were referred for a driving assessment. Odenheimer et al. (1994) also failed to find a relationship between head and neck flexibility and driving performance among drivers aged over 60. Finally, Tarawneh et al. (1993) failed to find a relationship between range of motion and on-road driving performance in drivers aged over 64.

People with reduced head and neck flexibility can improve this aspect of physical functioning through certain exercise regimes (Janke, 1994; Underwood, 1992; Waller, 1992). A study by Ostrow, Shaffron, and McPherson (1992) on drivers aged 60 or more involved half of the drivers completing an eight week, exercise-based program designed to improve range of motion, while the other half served as a control group. It was found that range of motion did improve for those who completed the exercise program. These improvements in flexibility were associated with improvements in an observation subscale of a driving assessment, indicating that they were better able to scan for hazards when driving. Similarly, McCoy, Tarawneh, Bishu, Ashman, and Foster (1993) also found improvement in the driving performance of drivers aged over 64 after an eight week exercise program designed to improve flexibility.

Loss of flexibility in the leg and hip joints is also potentially detrimental to driving ability due to its possible effect on pedal movements (Fildes, 1997). If this restriction of movement in these joints affects braking responses then there may be an increased crash risk. No studies, however, have examined the effects of leg and hip joint problems on driving outcome measures among older drivers. Related findings are that leg abnormalities have been found to be associated with adverse driving events (Marottoli et al., 1994), while walking speed, balance and gait are not related to crash involvement (Sims et al., 2000; Sims et al., 1998).

To summarise, physical functioning is thought to be important for driving but there has been little research linking physical problems to crash involvement or decrements in driving performance. Arm and shoulder strength have been studied a number of times but have not been found to be associated with driving outcome measures (e.g. Marottoli et al., 1998). However, studies of head-neck flexibility have produced a number of significant results (e.g. McPherson et al., 1988). The ability to rotate the head is necessary to detect hazards at intersections, when merging, and when changing lanes (e.g. Staplin et al., 1998b). Healthy legs and hips are thought to be important for foot pedal operations and, therefore, for braking but studies relating leg problems to driving outcome measures have been rare. Given that head-neck flexibility is the only aspect of physical functioning that has been found to be related to driving performance, this was chosen as the only physical functioning measure to be used in the present study.

3.7 Summary

Attempts to explain the increased crash risk of older drivers have led researchers to examine the medical and functional correlates of older driver crash involvement and on-road driving performance. General health and a number of individual medical conditions (cataract, glaucoma, dementia, cerebrovascular accidents, diabetes mellitus, epilepsy, and various medications) have been found to be related to these driving outcome measures, as have a number of functional abilities. The latter have included measures of vision (visual acuity, contrast sensitivity, and visual field), attention (switching, selective, and divided), other cognitive functions (mental status, visuospatial functioning, memory, and speed of information processing), and physical functioning (head-neck flexibility). On the basis of these findings, the present study into the driving behaviour and abilities of older drivers includes measures of medical conditions, medication use and each of these types of functional ability.

The issue for road safety authorities is how to respond to these findings that older drivers, as a group, have an elevated crash risk that is likely to be due to subgroups of the population affected by medical conditions and functional impairments. The following chapter addresses this issue, focussing, first, on attempts to identify drivers who have an elevated risk of crashing, and, secondly, on arguments that older drivers may be able to extend their driving lives, hence maintaining greater mobility, by restricting their exposure to difficult driving situations (so-called “self-regulation”).

CHAPTER 4: RESPONSES TO THE CRASH RISK OF OLDER DRIVERS: IDENTIFICATION OF DRIVERS AT GREATEST RISK OF CRASHING AND SELF-REGULATION OF DRIVING BEHAVIOUR

4.1 Introduction

Given that older drivers vary greatly in the extent to which their levels of functioning are negatively affected by aging and disease, and that various visual, cognitive and physical deficits are related to crash involvement and poorer on-road driving ability, there are likely to be subgroups of older drivers who are at an increased risk of adverse driving events. There are two possible responses to this problem. One is the screening of *all* older drivers to identify those likely to have an increased crash risk, who must then undertake an on-road driving assessment to determine their fitness to drive. The other does not utilise formal screening procedures for identifying at-risk older drivers but largely relies on older drivers assessing their own level of impairment and restricting their exposure to difficult driving situations accordingly ("self-regulation"). In the latter scenario, re-licensing assessments would be reserved for drivers who are referred to the licensing agency by medical practitioners on the basis of significant functional deficits or medical problems. In this chapter, issues surrounding the identification of at-risk drivers are discussed first, followed by a section concerned with research into older driver self-regulation.

4.2. Screening of Older Drivers

Many of the studies described in Chapter 3 that reported relationships between medical conditions or functional impairments and either crash involvement or poorer on-road driving performance were conducted in order to identify measures useful for screening of older drivers. It was hoped that test batteries could be developed that could reliably identify those whose licences should be cancelled because of an unacceptably high risk of crashing. However, a number of authors have claimed that screening of drivers is not an appropriate response to the presence of at-risk drivers in the driving population. That is, the notion that when drivers reach a certain age, they should be subjected to mandatory testing of some sort, has been judged to be a bad policy (Charlton, 2002; Hakamies-Blomqvist, 1996, 2003; Hakamies-Blomqvist, Johansson, & Lundberg, 1996; Hakamies-Blomqvist & Peters, 2000; Hull, 1991; Maycock, 1997).

One of the most compelling reasons for rejecting age-based screening is that studies have not found this practice to produce a safety benefit. Torpey (1986) looked at the crash rates of drivers aged 70 or more in Victoria, the only Australian state without any mandatory age-based assessment of any kind, and the crash rates of drivers in this age range in other Australian states. Torpey found that Victoria's crash rates for older drivers were comparable to those in the other states. Similarly, a study in the USA referred to by Hull (1991) compared the crash rates of older drivers whose driver's licences were renewed after re-testing and those whose licences were mailed out to them without any assessment of competency or health. It was found that there was no difference in crash rates between the two sets of older drivers.

Furthermore, Hakamies-Blomqvist et al. (1996) conducted a study that revealed that age-based driver screening may be counter-productive. This study was concerned with the effects on crash rates of the different licensing practices in Sweden and Finland. In Finland, drivers were required at age 70 to undertake rigorous medical screening in order to retain their driver's licences, while in Sweden, drivers retained their driver's licences for life, with no mandatory assessments at any age. It was found that, despite the differences in licensing practices, older driver crash rates per head of population in the two countries were similar. However, in Finland, there was an increased likelihood of older pedestrian fatalities. This occurred because many older drivers in Finland, particularly women, gave up their licences voluntarily rather than undertaking the re-licensing procedure, and thus became pedestrians rather than drivers. These drivers who voluntarily surrendered their licences were not those with a high likelihood of crashing but, due to physical frailty, were vulnerable as pedestrians (Hakamies-Blomqvist et al., 1996).

In addition to the potentially negative effect on crash rates caused by an increase in pedestrian activity among older adults, policies designed to identify drivers whose licences should be cancelled may lead to many drivers surrendering their licences prematurely (Charlton, 2002). This means that many older adults will be subjected to an unnecessary loss of mobility.

Many authors have described the importance to older adults of licensure and its associated mobility. Mobility for older adults has been linked most commonly to independence (Burns, 1999; Campbell et al., 1993; De Raedt & Ponjaert-Kristoffersen, 2000; Kostyniuk et al., 2000; Peel, Westmoreland, & Steinberg, 2002; Persson, 1993; Rabbitt, Carmichael, Shilling, & Sutcliffe, 2002; Underwood, 1992) and convenience (Adler et al., 1999; Burns, 1999; Eberhard, 1996; Persson, 1993). Although retirement brings an end to the need for work-related driving, most older adults continue to lead active lives and attend social gatherings, and mobility is essential for this (Fonda, Wallace, & Herzog, 2001; Freund & Szinovacz, 2002; Hakamies-Blomqvist, 2002; Harris, 2002; Klavora & Heslegrave, 2002; Lister, 1999; Marottoli et al., 2000; Peel et al., 2002). Driver's licences are often viewed as being symbolic of a person's competence (Persson, 1993) and so are also linked to older adults' self esteem (Kostyniuk et al., 2000; Underwood, 1992). In addition, older adults *without* licences make the same percentage of their trips in private vehicles as those *with* licences, suggesting that the unlicensed depend on others to drive them. Therefore, one older driver losing their licence could lead to the loss of mobility of a number of older adults (Rosenbloom, 2003).

Longitudinal studies have shown that the loss of mobility leads to increased depressive symptoms among older adults (Fonda et al., 2001; Marottoli, Mendes de Leon et al., 1997). Marottoli et al. (1997) studied older adults over a six year period and found that the largest increases in depressive symptoms occurred among those who had ceased driving, even after controlling for health-related and sociodemographic factors. Fonda et al. (2001) also conducted a longitudinal study of adults aged over 70 and found that the risk of worsening depressive symptoms between waves of data collection (separated by two to three years) was 1.44 times greater among those who had ceased driving. The authors concluded that programs designed to ward off driving cessation among older adults needed to be developed (Fonda et al., 2001). Using the same sample of older drivers as those used by Marottoli et al. (1997), Marottoli et al. (2000) found that driving cessation was also linked to decreased out-of-home activities. The authors concluded that the development of screening of older drivers should proceed with great caution, because unnecessarily stopping large numbers of older people from driving would have negative effects on their lifestyles and well-being.

This research on the negative effects of the loss of mobility has resulted in a shift of emphasis in the literature from identifying unfit drivers to highlighting the importance of maintaining older driver mobility (Hakamies-Blomqvist, 2003; OECD, 2001). The recent OECD report on the topic of older drivers concluded that two of the most important areas for future policy were “support and funding to enable lifelong mobility” and “support for older people to continue driving safely” (OECD, 2001. p121).

In summary, one response to the presence of older drivers with an increased crash risk, due to medical conditions or functional impairments, is to screen all older drivers to identify those who are unfit to retain their driver's licence. However, researchers have questioned the utility of mandatory testing of older drivers, citing the lack of evidence for a safety benefit associated with this practice (e.g. Hakamies-Blomqvist et al., 1996) and also the need for older adults to maintain mobility (e.g. Charlton, 2002).

One possible method of maintaining the mobility of older adults in spite of declining functional ability is to promote the self-regulation of driving behaviour. This involves drivers evaluating their own functional abilities and adjusting their driving behaviour accordingly. In this way, older adults may be able to remain active as drivers but reduce their exposure to conditions they find difficult (e.g. night driving).

4.3 Self-Regulation of Driving Behaviour

The term "self-regulation of driving behaviour" refers to the ability to monitor one's driving ability and adjust one's driving behaviour in accordance with this assessment, reducing exposure to driving situations one finds difficult (Charlton et al., 2001). The potential for older drivers to regulate their own driving behaviour has been identified as "central to current thinking about licence reassessment because if older drivers are self-regulating adequately, then there is less need for ... mandatory licence retesting" (Charlton, 2002, p51). Successful self-regulation should result in decreased older driver crashes through a reduction in exposure and, particularly, a reduction in exposure to difficult situations and conditions, whilst still allowing the maintenance of mobility (Stalvey & Owsley, 2000). The following sections discuss previous research looking at the extent to which older drivers do self-regulate, whether this self-restriction reflects sound judgement of declining abilities, and whether this self-regulation reduces crash risk.

4.3.1 Types of Older Driver Self-Regulation

Not only do older drivers travel fewer kilometres per year than drivers in younger age groups (Lyman et al., 2002; Maycock, 1997; OECD, 2001; Ryan et al., 1998) but there are also qualitative changes in older adults' driving behaviour. These changes have usually been assessed by ascertaining the driving situations or conditions older drivers tend to avoid. The condition most commonly avoided by older drivers is driving at night (Ball et al., 1998; Charlton et al., 2001; Chu, 1994; Cooper, 1990b; Daigneault et al., 2002a; Eberhard, 1996; Fildes, Lee et al., 1994; Forrest et al., 1997; Gallo et al., 1999; Hakkinen, 1984; Hennessy, 1995; Holland & Rabbitt, 1994; Kline et al., 1992; Kostyniuk et al., 2000; Lundqvist et al., 2000; Parasuraman & Nestor, 1991; Rabbitt, Carmichael, Jones, & Holland, 1996; Raitanen, Tormakangas, Mollenkopf, & Marcellini, 2003; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998; Yee, 1985). Other conditions that tend to be avoided by older drivers are:

- inclement weather (Forrest et al., 1997; Gallo et al., 1999; Hakkinen, 1984; Lundqvist et al., 2000; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998);
- busy traffic, either in the form of high traffic roads or peak hour traffic times (Ball et al., 1998; Chu, 1994; Cooper, 1990b; Fildes, Lee et al., 1994; Gallo et al., 1999; Holland & Rabbitt, 1994; Kline et al., 1992; Rabbitt et al., 1996; Raitanen et al., 2003; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998; Tasca, 1992; Yee, 1985);
- high speed roads, such as freeways (Chu, 1994; Eberhard, 1996; Fildes, Lee et al., 1994; Tasca, 1992);
- unfamiliar areas or roads (Burns, 1999; Charlton et al., 2001; Eberhard, 1996; Forrest et al., 1997; Parasuraman & Nestor, 1991; Raitanen et al., 2003); and

- unprotected turns across traffic or at complex junctions (Fildes, Lee et al., 1994; Holland & Rabbitt, 1994).

Older drivers also report deliberately driving more slowly than other drivers (Carr et al., 1992; Chu, 1994; Daigneault et al., 2002a; Forrest et al., 1997; Hakamies-Blomqvist, 1996; OECD, 1985; Parasuraman & Nestor, 1991; Tasca, 1992; Wood, 2002a). Reductions in overall driving exposure by older drivers result more from shorter driving trips than a smaller number of trips (Chu, 1994; Eberhard, 1996; Forrest et al., 1997; Freund & Szinovacz, 2002; Holland & Rabbitt, 1994; OECD, 1985; Tasca, 1992).

Reports on the extent of self-regulation of older drivers may vary, however, across different populations. Ball et al. (1998) and Stalvey and Owsley (2000) both asked older drivers about their avoidance of difficult driving situations but responses in the two studies were very different. Ball et al. (1998) surveyed drivers aged 55 or over and found that the most commonly avoided driving situation was night driving, with over 80% of drivers reporting that they avoided it "often" or "always". It was also found that older drivers very commonly avoided peak hour traffic, with approximately 70% avoiding it "often" or "always". Older adults also reported avoiding high speed interstate roads and high traffic roads, with less avoidance of driving in the rain, driving alone, and performing turns across traffic. For driving alone and performing turns across traffic, over 40% reported never avoiding these situations. Stalvey and Owsley (2000) surveyed drivers aged over 64 who had been in a crash in the previous year and who had impaired visual acuity or impaired Useful Field of View (UFOV). The extent of driving avoidance demonstrated by this group was much less than that of the sample in the Ball et al. study. Each driving situation was reported as "never" being avoided by 50% or more of respondents. Consistent with Ball et al., however, the greatest amount of avoidance was for night driving and the least was for driving alone (Stalvey & Owsley, 2000).

Differences in the responses of the two different samples in Ball et al. (1998) and Stalvey and Owsley (2000) emphasise the importance of determining the correlates of older driver self-regulation. It is not enough to know that many drivers restrict their driving; it is necessary to ascertain which drivers are self-regulating and why.

4.3.2 Correlates of Self-Regulation

A number of studies have been conducted to determine not only the extent of self-regulation but also its correlates. These correlates have included difficulty with specific driving conditions, declines in health and functional abilities, age, gender, and retirement.

4.3.2.1 Driving Difficulty

A driver may reduce their exposure to certain driving conditions as a result of experiencing difficulties with that condition. The extent to which older drivers have reported difficulties in the situations or conditions they are known to avoid has been assessed in a number of studies.

One study asked older drivers about difficulties experienced while driving (Fildes, Lee et al., 1994), and revealed that older drivers reported troubles with the visual demands of driving, particularly seeing at night, coping with glare, checking blind spots, and reading signs. Turning at complex intersections was also nominated as a difficult driving task, with the drivers reporting problems with assessing the speeds of oncoming cars and making safe gap judgements. Also problematic was changing lanes in heavy traffic. A follow up survey of young (under 40) and older (over 60) drivers confirmed that older drivers reported problems with driving at night, in heavy traffic, and through busy intersections (Fildes, Lee et al., 1994).

Rabbitt and associates (Rabbitt et al., 1996; Rabbitt et al., 2002) have conducted cross-sectional and longitudinal studies into self-reported driving difficulties of older drivers. Rabbitt et al. (1996) sent questionnaires to 1,780 drivers aged over 54, with 395 of these drivers being followed up five years later (Rabbitt et al., 2002). Once again, older drivers claimed to have problems driving in low luminance conditions and coping with glare. They also had problems with maintaining alertness over a long period, dividing their attention between competing tasks, and parking. Judgements of the speed of other vehicles and associated safe-gap judgements were not reported as problematic (Rabbitt et al., 1996). The longitudinal data from the second study (Rabbitt et al., 2002) largely confirmed the findings of the cross-sectional study. However, the second study additionally found that self-reported difficulty with different driving scenarios was negatively correlated with self-reported mileage, suggesting that perceived difficulties with driving were related to self-restriction of driving. This relationship remained after controlling for medical conditions. Rabbit et al. (2002, p16) concluded that "it is perceptions of changing competence and confidence, perhaps associated with declining health, rather than the experience of declining health per se, that brings about appropriate modifications of driving behaviour".

Cooper (1990b) sent questionnaires about driving to adults aged over 54 and found that the driving scenarios that produced the greatest difficulty for older drivers were changing lanes in heavy traffic, turning at intersections, and driving at night. These difficulties were reflected in the driving behaviour of those surveyed, with many older drivers avoiding night driving and peak hour traffic. There was also an increasing tendency with age to avoid driving in inclement weather. Cooper (1990b) concluded that older drivers did note the driving situations that caused them problems and sought to avoid these situations if possible.

Finally, a study was conducted by Kostyniuk, Shope, and Molnar (2000) in which a random sample of drivers aged over 64 were interviewed over the telephone regarding driving difficulties and avoidance. In this study, drivers were classified according to whether or not they thought there was a "real chance" that they would experience problems with their driving ability in the next five years. Those who anticipated driving problems in the near future reported less comfort in a number of driving situations than those who did not anticipate future driving problems. These situations included driving in the rain, turning across traffic at busy intersections, merging onto busy highways, reversing, keeping up with other traffic, and driving at night. Nervousness about driving was generally low among the sample as a whole but higher among those anticipating future problems (Kostyniuk et al., 2000).

4.3.2.2 Declining Health and Functional Ability

If self-regulation is to reduce crash involvement among older drivers without unnecessarily restricting mobility, then self-regulation should be associated with declines in health and functional ability, given that such declines have been found to be related to driving measures (see sections 3.2 to 3.6). A number of studies have therefore examined the relationship between self-regulation and drivers' health and functional abilities.

Driver health has been found in a number of studies to be related to self-regulation (Burns, 1999; Forrest et al., 1997; Freund & Szinovacz, 2002; Gallo et al., 1999; Kington, Reuben, Rogowski, & Lillard, 1994; Kostyniuk et al., 2000; Marottoli et al., 1993; Rabbitt et al., 2002; Raitanen et al., 2003; Rimmo & Hakamies-Blomqvist, 2002). For example, Rabbitt et al. (2002) found that increases over time in self-reported medical complaints were associated with decreases in both mileage and self-reported driving competence. These associations remained after controlling for age. However, as noted previously (see section 4.3.2.1.), changes in mileage were predicted by self-reported driving difficulty more than by self-reported health problems (Rabbitt et al., 2002).

Forrest et al. (1997) sent questionnaires to women aged over 70 and found that decreased driving was related to falls, fractures, poor hearing, muscle pain, and myocardial infarction. It was concluded that physical functioning mediated this relationship. Being affected by a combination of different medical conditions was also common among those drivers who reduced their driving (Forrest et al., 1997). Raitanen et al. (2003) looked at reductions in driving among adults aged over 54 and found that reduced driving was associated with chronic medical conditions. Kostyniuk et al. (2000) found that anticipation of future driving problems, which was associated with self-reported driving difficulty and avoidance of certain driving conditions, was related to lower self-reported health

Specific aspects of functioning that have been studied in relation to self-regulatory behaviour and driving include vision and visual attention (Ball & Owsley, 1991; Ball et al., 1998; Gallo et al., 1999; Hennessy, 1995; Kington et al., 1994; Kostyniuk et al., 2000; Owsley et al., 1999; Stalvey & Owsley, 2000; Stutts, 1998). Owsley et al. (1999), for example, looked at the driving behaviour of 384 drivers aged over 54, including 279 who had been diagnosed with cataract. It was found that, compared to controls, those with cataract drove fewer miles, fewer days per week, to fewer destinations, were more likely to limit driving to areas near their homes, preferred others to be the driver and drove more slowly than general traffic. They were also more likely to report difficulties with driving in the rain, alone, on interstate highways, on high traffic roads, during peak hour, at night, and performing turns across traffic. Those who had difficulties with these situations were more likely to report avoiding them. Hennessy (1995) found that vision and visual attention were associated with specific types of driving avoidance, including night driving, inclement weather, turns across traffic, and heavy traffic. However, the amount of variance in avoidance measures explained by vision test scores was less than 7% in all cases. Stutts (1998) looked at driving exposure, driving avoidance, and visual functioning of drivers aged 65 or more and found that visual impairment was related to both reduced exposure and avoidance of specific situations. Contrast sensitivity was the best predictor of driving exposure of the vision tests used (contrast sensitivity, high and low contrast acuity, peripheral vision).

Stalvey and Owsley (2000), however, found that impairments of vision and visual attention were not associated with self-regulatory practices. Based on a sample of drivers aged over 65 who had been in a crash in the previous year and had impaired visual acuity or visual attention, this study revealed that the majority of these drivers were unaware of their impairment and so saw no reason to restrict their driving behaviour. Specifically, 91% of drivers agreed that impaired vision affects driving ability and 89% claimed that impaired vision would be noticeable. However, 70% of these drivers rated their vision as “excellent” or “good”, 82% reported no difficulty with handling challenging driving situations, and 75% of drivers rarely or never avoided these situations. Seventy percent of the sample also stated that they were capable of regulating their driving behaviour. The authors concluded that drivers needed to be made aware of their impairment in order to respond to it with avoidance of difficult driving situations. Drivers, they claimed, were not skilled at assessing their own level of functioning (Stalvey & Owsley, 2000).

Cognitive functioning is another variable that is relevant to driving ability and appears to influence the degree of self-regulation. Specifically, a number of authors have argued that self-regulation tends to be deficient in those who demonstrate cognitive problems, probably due to an impaired awareness of these problems (Adler et al., 1999; Ball & Owsley, 1991; Ball et al., 1998; Cotrell & Wild, 1999; Eberhard, 1996; Lesikar et al., 2002; Lundberg et al., 1997; Rizzo et al., 2001).

Adler et al. (1999) conducted a study looking at older drivers with dementia to see whether they were able to monitor their abilities and adjust their driving accordingly. Although 51% of drivers had adjusted their driving behaviour in the last year, over a third of the drivers with dementia drove daily, while many drove frequently at night, on freeways, in heavy traffic, and alone. The study did not include an assessment of the driving abilities of the drivers but dementia severity, in terms of Mini Mental State Examination (MMSE) performance and duration of memory loss, was not found to be related to adjustment of driving behaviour. Other important findings were that the majority of drivers thought that they were the best people to judge whether or not they could drive and that the majority of drivers did not think they would ever have to cease driving. It was concluded that many drivers with dementia lack insight into their driving abilities and the fact that their driver's licence may have to be relinquished (Adler et al., 1999).

Cotrell and Wild (1999) also studied the driving behaviour and awareness of drivers with dementia (DAT). Patients rated themselves as less impaired than did their caregivers, with the differences between ratings being related to declines in the MMSE performance of the patients. Most drivers had adjusted their driving behaviour following a diagnosis of DAT, with unfamiliar roads being the most avoided driving condition. Avoidance of unfamiliar roads and heavy traffic was found to be associated with driver awareness of declining attentional abilities. The authors argued that this association was due to drivers who were aware of declining attentional abilities avoiding situations with heavy attentional loads (e.g. unfamiliar roads and heavy traffic). They concluded that drivers with DAT generally restricted their driving but that those with an awareness deficit failed to do so (Cotrell & Wild, 1999).

Studies into the relationship between cognitive ability and self-regulation, which do not specifically include drivers with DAT, have produced inconsistent results. Ball et al. (1998) found that those drivers aged over 54 who had low mental status scores reported less avoidance of difficult driving situations than those who had impaired vision or visual attention but good mental status scores. Stutts (1998), on the other hand, administered tests of vision and cognition to drivers aged over 64 and found that deficits in cognitive functioning were related to reduced driving exposure and greater avoidance of difficult driving conditions. Reduced driving was more strongly associated with deficits in cognitive functioning than with deficits in vision. However, Stutts noted that there were still many drivers in the lowest quartile of cognitive ability who were driving well over the average mileage driven by those aged over 64 (Stutts, 1998). Freund and Szinovacz (2002), in a study of adults aged over 69, found that deficits in mental status were related to driving cessation in women and reduced driving exposure in men. However, there was no analysis of avoidance of particular driving situations.

4.3.2.3 Other Correlates of Self-Regulation

Studies into self-regulation have identified a number of additional correlates beyond driving difficulty, health status, and functional abilities. Specifically, self-regulation has been found to be associated with increased age, female gender, and retirement from the work force.

A finding that has often been reported in the literature is that there is greater self-regulation with increasing age (Burns, 1999; Charlton, Oxley, Fildes, Oxley, & Newstead, 2003; Forrest et al., 1997; Freund & Szinovacz, 2002; Gallo et al., 1999;

Holland & Rabbitt, 1994; Raitanen et al., 2003; Rimmo & Hakamies-Blomqvist, 2002). For example, Rimmo and Hakamies-Blomqvist (2002) analysed questionnaires from drivers aged over 54 and found that avoidance of difficult conditions increased with age, with the largest increases being for driving at night. Age, combined with gender, accounted for 28% of the variance in driving avoidance, greatly exceeding the contribution of health factors (2%). Holland and Rabbitt (1994) administered questionnaires to drivers aged over 50 and found that, with increasing age, there was an increasing tendency to avoid complex intersections, night driving, and distance driving, but not peak hour traffic. It was also found that years of driving experience were negatively correlated with driving avoidance, so that the effects of age on avoidance were stronger when the effects of years of driving experience were controlled statistically. Forrest et al. (1997) studied the driving behaviour of women aged over 70 and found that, with increasing age, there was greater avoidance of driving in snow, at night, on highways, on unfamiliar roads, and on long trips. Older drivers also tended to drive less overall and more slowly. There was, however, no reduction with age in the frequency of driving overall, or in driving at peak hour (Forrest et al., 1997).

Another demographic variable associated with self-regulation of driving behaviour is gender, with females being more likely to restrict their driving than males. Burns (1999) collected questionnaires from drivers aged between 21 and 85 and found that women were more likely than men to avoid unfamiliar roads, in addition to recording lower total mileage. Similar results were found by Charlton et al. (2003) in a survey of drivers aged over 55. Gallo et al. (1999) and Rimmo and Hakamies-Blomqvist (2002) both found that avoidance of difficult driving conditions, such as night, peak hour, and bad weather, was more common among women than men. As stated previously, Rimmo and Hakamies-Blomqvist (2002) found that the contribution of gender to prediction of driving avoidance exceeded that of health factors. Raitanen et al. (2003) found that women were more likely than men to avoid driving in unknown areas and bad road conditions.

Another factor that is associated with reduced driving by older drivers but is unrelated to safety is retirement. When retired, drivers are able to choose when they drive and can avoid peak hour traffic and difficult conditions (Ball et al., 1998; Cooper, 1990b; Eberhard, 1996; Fildes, Lee et al., 1994). Decreased mileage is also related to cessation of work-related driving and reductions in income (Burns, 1999; Fildes, Lee et al., 1994; Rabbitt et al., 2002). Burns (1999), for example, found that 28% of a sample of older drivers reported that the amount of driving they did was reduced because of the expense of maintaining a vehicle.

Other factors found to be positively related to self-regulation include having a partner who is able to drive (Freund & Szinovacz, 2002), low socioeconomic status (Freund & Szinovacz, 2002), and an urban location of residence (Burns, 1999). The latter association was due to older adults in rural areas having few alternative transport options to access essential services.

One more factor that would be expected to be related to self-regulation of driving behaviour is that of previous crashes. If older drivers engage in self-regulation to enhance their safety, then it is likely that drivers who have been involved in crashes would be more motivated to regulate their driving behaviour. Studies looking at driving behaviour of crash-involved older drivers, however, have produced mixed results. Ball et al. (1998) found that avoidance of rain, turns across traffic, and peak hour traffic was associated with previous crash involvement. Daigneault et al. (2002a) looked at the driving behaviour of two groups of male drivers aged over 65: one group consisting of drivers free of crash involvement in the previous five years and the other including drivers with three or more crashes in the same time period. It was found that self-regulation of driving behaviour was common among both sets of drivers but, contrary to

Ball et al. (1998), there was no difference between the two groups of drivers in terms of driving frequency or the avoidance of difficult driving situations, except that the crash-involved drivers reported reducing their driving speed in the previous five years.

One reason for assessing the correlates of self-regulation is so that any barriers to self-regulation can be identified. For example, the finding by Burns (1999) that self-regulation is correlated with an urban location of residence indicates that living in a rural location may be a barrier to self-regulation for older drivers. Stalvey and Owsley (2000) developed a questionnaire specifically to measure possible barriers to self-regulation of driving by older drivers: the Driving Perceptions and Practices Questionnaire. They administered the questionnaire to a sample of drivers aged over 65 who had been involved in a crash in the previous year and found the following:

- 75% of drivers thought the lack of adequate public transportation made self-regulation more difficult,
- 57% of drivers had few relatives or friends who were available if it was necessary for someone else to drive them,
- 54% claimed that maintenance of their lifestyle would not permit restriction of driving behaviour, and
- 36% had other people who were dependent on them for driving (Stalvey & Owsley, 2000).

Therefore, self-regulation of driving behaviour is a complex phenomenon associated with many other variables, including difficulty with certain driving conditions (e.g. Rabbitt et al., 2002), declines in visual and attentional functioning (e.g. Ball et al., 1998), intact cognitive functioning (e.g. Ball et al., 1998), decreased health (e.g. Forrest et al., 1997), older age (e.g. Rimmo & Hakamies-Blomqvist, 2002), female gender (e.g. Burns, 1999), and retirement from the work force (e.g. Fildes, Lee et al., 1994). There is also some evidence that self-regulation is associated with the absence of barriers to self-regulation. Such barriers include a rural residence, lack of public transport, the lack of relatives or friends to help with mobility, an active lifestyle felt to require unrestricted driving, and the dependence of other people for mobility (e.g. Stalvey & Owsley, 2000).

4.3.3 The Relative Success of Self-Regulation

It is promising to find that a sizeable proportion of older drivers regulate their driving and that this self-regulation is associated with variables that are related to driving ability. However, this still does not establish whether this self-regulation is successful. First, as self-evaluation is critical for the process of self-regulation (Purdie & McCrindle, 2002), it needs to be established that older drivers are good at judging their own driving capabilities. If older drivers lack insight into declining driving ability, adequate self-regulation will not be possible. Secondly, it needs to be established that self-regulation of driving behaviour results in lower crash involvement among those older drivers who practise it.

4.3.3.1 The Accuracy of Self-Evaluations

A small number of researchers have asked older drivers for self-evaluations of their driving abilities, both generally and with regard to specific situations, and attempted to evaluate their accuracy. These studies have been conducted using a range of methodologies. Cooper (1990b) judged older drivers' self-evaluations on the basis of crash patterns of older drivers in general. Holland (1993) compared older drivers' self evaluations with their evaluations of other drivers of their own and other age groups. Holland and Rabbitt (1994) compared older drivers' self evaluations with driving instructors' evaluations of older drivers in general. However, the best methodology to determine the accuracy of driver self-evaluation is to assess the *actual* driving abilities of drivers.

Cushman (1996) conducted a study of drivers aged over 54, 25 percent of whom had suspected DAT, in which participants were asked about their driving ability and behaviour, and completed a test of on-road driving ability. Most drivers who performed below acceptable standards on the driving test reported no significant problems with driving and saw themselves as being average or above average drivers. Cushman noted that the self-regulation of driving would not occur in drivers who were unaware of their problems. The lack of awareness of decreased driving ability among Cushman's sample could be due to low mental status, given that the sample included an over-representation of drivers with dementia. As noted previously (see section 4.3.2.2), low mental status may be associated with decreased awareness of deficits and the absence of self-regulatory practices.

Marottoli and Richardson (1998) assessed the on-road driving performance of drivers aged over 76 after asking them to rate their driving ability and confidence in difficult driving situations. Consistent with Cushman (1996), all rated themselves as average or above average drivers but approximately a quarter of the drivers had moderate or major difficulties in the driving test. Those drivers for whom there was a substantial discrepancy between self-rated and actual driving ability were found to be older and to have more self-confidence than the remainder of the sample. Confidence and self-reports of driving ability were positively related to each other and to driving frequency but were not related to driving performance or previous crash and violation history. The authors concluded that objective evidence of driving ability has no impact on the confidence or self-ratings of driving ability of older drivers (Marottoli & Richardson, 1998).

An Australian study that directly investigated the relationship between self-regulation of driving behaviour among older drivers (> 84 years) and on-road driving ability was conducted by Charlton et al. (2001). It was found that 80% of those who did not avoid difficult driving situations passed the driving test. Of those who used one self-regulatory practice but who drove more than four days per week, 70% passed the test. Of those who drove less than four days per week, 50% passed. The authors concluded that self-regulation of driving was not reliably associated with driving performance and added that there were some drivers with poor driving skills who did not self-regulate. Charlton et al., however, acknowledged that the study used a very restricted sample. By the age of 85, a large proportion of older drivers have ceased driving and it could be that these older adults were better at self-regulation than those still driving well into their eighties (Charlton et al., 2001).

The findings of these three studies into the relationship between on-road driving performance and either self-regulation of driving behaviour or self-ratings of driving ability suggest that many drivers are unaware of their declining driving abilities and do not alter their driving behaviour. However, none of these studies used representative samples of older drivers. Both Charlton et al. (2001), as noted above, and Marottoli and Richardson (1998) used samples of very old drivers, while Cushman's (1996) sample included an over-representation of drivers suspected of having dementia. Both of these sampling procedures potentially biased the results in favour of finding that older drivers were not good at evaluating their own driving ability and adjusting their driving behaviour accordingly.

4.3.3.2 The Relationship Between Self-Regulation and Crash Involvement

The success of older drivers' self-regulation can be measured by comparing the crash involvement of those drivers who restrict their driving with those who do not. If self-regulation is effective, self-regulating older drivers would be expected to be involved in less crashes than non-regulating drivers. However, Gallo et al. (1999, p335) noted that restriction of driving behaviour may be a “double-edged sword”, in that it may be a sensible response to difficulties with certain driving conditions but may also signify impending loss of the ability to drive. Hakamies-Blomqvist (1994) argued that if drivers avoid difficult conditions, they lose the skills necessary to deal with those conditions and, if required to drive in them, have a greater crash risk than those who have not avoided difficult conditions. Thus, self-regulation may result in certain driving skills not being maintained, which may lead to an elevated crash risk.

Studies that compare the crash involvement of drivers who do and do not self-regulate would ideally use prospective data but some have used data on retrospective crashes as a proxy measure for prospective crashes. A major problem associated with this choice in studies of adjustment of driving behaviour is the possibility that current driving practices reflect changes enacted in response to previous crashes. This would mean that a higher rate of previous crashes among those who self-regulate would not justify the conclusion that self-regulation fails to guard against crash involvement because the self-regulation may have only occurred after these crashes, as a direct response to them.

An example of a study using retrospective crash data is that of Daigneault et al. (2002a) who compared the driving behaviour of two groups of drivers aged over 64. One of the groups consisted of drivers who had recorded no crashes in the previous five years and the other was of drivers who had recorded three or more. The two groups reported equivalent amounts of avoidance of difficult driving situations, although the crash-involved group was more likely to report driving more slowly than other drivers. However, these results are difficult to interpret because it is possible that the crash-involved group did not self-regulate their driving until prompted to by their crash involvement. It is possible that this group of drivers adjusted their driving behaviour only after crashing, in a manner similar to those drivers in the other group whose self-regulation had successfully guarded against crashing in the previous five years. The authors acknowledged this, saying that they did “not know if these adaptive behaviours were already present before the accidents (implying that they were not effective...) or if changes in these adaptive behaviours came after having many accidents” (Daigneault et al., 2002a, p233).

Hennessy (1995) used retrospective crash data over a three year period to look at the relationship between vision tests, age group, restriction of driving, and crash risk among licence renewal applicants. The avoidance of difficult driving situations and age group was found to mediate the relationship between vision and recent crash history. For example, among drivers aged 26 to 39, those with poor contrast sensitivity who did *not* restrict their driving in heavy traffic had higher crash involvement than those with good contrast sensitivity, who, in turn, had higher crash involvement than those with poor contrast sensitivity but who *did* restrict their driving in heavy traffic. However, self-regulation was not found to reduce the crash involvement of drivers aged over 70 (Hennessy, 1995). Once again, it is unclear whether self-regulation was practised before or after involvement in a crash.

Cooper (1990b) analysed the crash patterns of older drivers in general, and the self-reported driving avoidance of a sample of older drivers. The author concluded that older adults recognised the problems posed by intersections and adverse driving conditions but reduced exposure to these conditions was not sufficient to compensate for the additional risks they pose (Cooper, 1990b). However, the study was weakened by the use of crash data for older drivers generally, rather than that of the sample of drivers whose avoidance behaviour was analysed.

A study that analysed prospective crash data for older drivers engaged in varying degrees of self-regulation was conducted by Ball et al. (1998) in the USA. Using a sample of drivers aged over 54, the researchers found a relationship between the avoidance of difficult driving situations and previous crashes but could not find any relationship between driving avoidance and subsequent crashes across a three year time period. The latter finding was attributed to a high level of subsequent attrition among the functionally impaired drivers in their sample (Ball et al., 1998). Another study using prospective crash data was that by Lesikar et al. (2002). In this study, self-reported changes in driving abilities or behaviour were found to be related to crash involvement in a two year period among a sample of drivers aged over 64. However, the assessment of changes in driving behaviour lacked detail and only 10 of the drivers were involved in a crash in the subsequent two years (Lesikar et al., 2002). Therefore, the reliability of these results is questionable.

The relationship between self-regulation of driving behaviour among older drivers and crash involvement is, therefore, unclear. Although there is little evidence suggesting that self-regulation is beneficial for drivers who implement it compared to those who do not, there is also no reliable evidence to the contrary.

4.3.4 Cessation of Driving

The most extreme form of self-regulation of driving is cessation of driving. A number of researchers have reported that cessation occurs for many drivers as a culmination of the gradual restriction of driving (Dellinger et al., 2001; Hakamies-Blomqvist & Wahlstrom, 1998; Persson, 1993). An example of the typical progression of an older driver from self-regulation to cessation was given by Persson. First, older drivers typically stop driving at night or in heavy traffic and then begin reducing their exposure overall. This is followed by no longer carrying passengers, especially grandchildren, and then by always driving with a co-pilot. When the driver is affected by increased health problems, has a crash, or moves to a retirement community, they may finally cease driving altogether. The alternative pattern to this is immediate driving cessation in response to a sudden event like a stroke (Persson, 1993).

Detailed studies of driving cessation among older adults have been conducted more than those of self-regulation, and the precursors and correlates of cessation are now well-understood. Cessation of driving has been found to be linked to:

- declining general health or being affected by a combination of different medical conditions (Campbell et al., 1993; Dellinger et al., 2001; Fonda et al., 2001; Forrest et al., 1997; Freund & Szinovacz, 2002; Gallo et al., 1999; Hakamies-Blomqvist & Wahlstrom, 1998; Harris, 2002; Jette & Branch, 1992; Kington et al., 1994; Marottoli, Mendes de Leon et al., 1997; Marottoli et al., 1993; O'Neill, Bruce, Kirby, & Lawlor, 2000; Persson, 1993; Rabbitt et al., 1996),
- age-related macular degeneration (Campbell et al., 1993; Eberhard, 1996; Forrest et al., 1997),
- cataract (Forrest et al., 1997; Marottoli et al., 1993),
- retinal haemorrhage (Campbell et al., 1993),
- self-reported problems with vision (Dellinger et al., 2001; Forrest et al., 1997; Freund & Szinovacz, 2002; Kington et al., 1994; Kostyniuk et al., 2000),
- cognitive impairment, including dementia (Foley, Masaki, Ross, & White, 2000; Valcour, Masaki, & Blanchette, 2002)
- cerebrovascular accidents (Campbell et al., 1993; Eberhard, 1996; Forrest et al., 1997; Freund & Szinovacz, 2002; Marottoli, Mendes de Leon et al., 1997; Persson, 1993; Stewart et al., 1993),

- Parkinson's Disease (Campbell et al., 1993; Dellinger et al., 2001; Eberhard, 1996; Freund & Szinovacz, 2002; Marottoli, Mendes de Leon et al., 1997; Stewart et al., 1993),
- increasing age (Campbell et al., 1993; Dellinger et al., 2001; Foley, Heimovitz, Guralnik, & Brock, 2002; Fonda et al., 2001; Forrest et al., 1997; Freund & Szinovacz, 2002; Gallo et al., 1999; Kington et al., 1994; Marottoli, Mendes de Leon et al., 1997; Marottoli et al., 1993),
- female gender (Campbell et al., 1993; Foley et al., 2002; Gallo et al., 1999; Kington et al., 1994; Marottoli, Mendes de Leon et al., 1997; Marottoli et al., 1993),
- low income (Freund & Szinovacz, 2002; Jette & Branch, 1992; Marottoli et al., 1993), and
- living in an urban area (Freund & Szinovacz, 2002; Kington et al., 1994; Marottoli, Mendes de Leon et al., 1997).

Cessation of driving is therefore related to a number of the same factors as self-regulation, consistent with the suggestion that cessation may be viewed as an extreme form of self-regulation. However, not all factors investigated by researchers have been found to be related to cessation of driving. Inconsistent results have been found for cardiovascular conditions and diabetes, while previous crashes (Campbell et al., 1993; Dellinger et al., 2001) and arthritis (Forrest et al., 1997; Freund & Szinovacz, 2002; Gallo et al., 1999) have consistently been found *not* to be related to cessation. With regard to arthritis, Kington et al. (1994) actually found that those with arthritis were *more* likely to drive than those without it, possibly because public transportation failed to accommodate those with functional impairments and restricted physical mobility.

4.3.5 Summary

Central to current thinking about older drivers is that their crash involvement could be kept to a minimum through the avoidance of driving situations they find difficult ("self-regulation"). For this to prove effective, older drivers would need to adjust their driving behaviour in accordance with their functional and driving abilities.

Studies of the self-regulatory practices of older drivers have found that the most commonly avoided driving condition is night driving (e.g. Charlton, 2002). Inclement weather, busy traffic, high speed roads, unfamiliar roads, and unprotected turns across oncoming traffic are also commonly avoided (e.g. Fildes, Lee et al., 1994). Older drivers also often report driving more slowly and taking shorter trips (e.g. Forrest et al., 1997). Self-regulation is associated with self-reported problems with specific driving situations or conditions (e.g. Rabbitt et al., 2002), and poor health or medical conditions (e.g. Forrest et al., 1997). In particular, drivers with visual problems or eye conditions often limit their driving (e.g. Owsley et al., 1999), as do those with deficits in visual attention (e.g. Ball et al., 1998). In contrast, substantial declines in cognitive ability, such as those that occur with dementia, appear to decrease the likelihood of adequate self-regulation because they compromise drivers' awareness of their declining abilities (e.g. Adler et al., 1999). However, some studies have produced contradictory findings (e.g. Freund & Szinovacz, 2002). Other factors found to be related to self-regulation have included increased age, female gender, and retirement from work (e.g. Burns, 1999).

Less clear is the success of older drivers' self-regulation. There are very few studies comparing older drivers' self-ratings of driving ability or level of driving restriction with actual on-road ability, and those that have done so have not used representative samples of older drivers (e.g. Charlton et al., 2001). It has also not been reliably established whether subsequent crash risk is reduced among drivers who self-regulate.

When functional and driving ability declines enough, the self-regulating older driver will often decide to cease driving. Cessation of driving among older adults has been studied more than self-regulation and its correlates are well known, including various medical conditions, declines in various types of functioning, and demographic factors.

4.4 Summary of the Literature on Older Drivers

In the coming decades, there will be substantial increases in the amount of driving done by drivers aged over 65, due to an aging population, an increased level of licensure among older adults, and longer distances being driven by these licensed older drivers. For this reason, considerable attention has been paid in recent years to the crash patterns of older drivers. Older drivers have been found in previous research to be over-involved in crashes on a per kilometres driven basis, and in Chapter 2, an analysis of the crash patterns by age group for South Australian drivers replicated this finding. Given this greater crash risk among older drivers and the likelihood that older driver crashes will increase in future, road safety authorities are keen to develop means by which to reduce older driver crash involvement.

There is a vast literature documenting the correlates of crash involvement and declines in on-road driving ability among older drivers. These correlates include various medical conditions (cataract, glaucoma, dementia, CVAs, diabetes, epilepsy), use of various medications, visual problems (lower visual acuity, lower contrast sensitivity, restricted visual fields), attentional deficits (switching attention, selective attention, divided attention), lower mental status, visuospatial deficits, poorer memory (especially visuospatial working memory), slower speed of information processing, and reduced head-neck flexibility. Given the range of correlates of driving ability among older drivers, attempts have been made to develop methods of screening older drivers to identify those whose licences should be cancelled because of a sufficiently increased crash risk. The utility of screening older drivers has been questioned, however, given that it is likely to be costly, that its road safety benefits have not been established, and that it would result in the loss of mobility for many older adults.

Another method of reducing older driver crashes without severe restriction of mobility is that of self-regulation, allowing older drivers to monitor their own functional abilities and driving performance, and to adjust their driving behaviour accordingly. This adjustment of driving behaviour often takes the form of avoidance of difficult driving situations. Night driving is the most commonly avoided driving situation but older drivers also often report avoiding inclement weather, busy traffic (peak hour and busy roads), high speed roads (e.g. freeways), unfamiliar roads, and unprotected turns across oncoming traffic. They also often drive more slowly and report making fewer long trips.

If self-regulation is to be encouraged, older drivers need to be able to recognise and respond to declining capabilities. Self-regulation of driving behaviour by older drivers has been found to be related to eye conditions, visual problems, visual attention deficits, increased age, female gender, retirement from work, and difficulties with specific driving situations. In contrast, decreased mental status, often associated with dementia, makes self-regulation less likely, although some findings have contradicted this. The adequacy of self-regulation by older drivers remains unclear, with no studies reliably demonstrating whether self-regulation by older drivers is related to driving ability or whether it guards against subsequent crash involvement.

4.5 The Present Thesis

On the basis of the information provided in Chapters 1 through 4, it is important for road safety and licensing authorities to ascertain the extent to which older drivers engage in self-regulation and the extent to which self-regulatory practices are related to drivers' functional and driving capabilities. This study has therefore been designed to measure the self-regulation of driving behaviour of older drivers in South Australia, and to examine correlations between this self-regulation, and functional and driving performance.

To this end, older drivers were asked to provide details of their driving behaviour and various driving-related beliefs and attitudes. Specifically, they were asked to provide self-ratings of their driving and driving-related abilities (vision, dual task ability), ratings of their confidence in difficult driving situations, details of recent adverse events (crashes or violations), overall driving exposure (and reasons for any recent reductions in driving), and avoidance of difficult driving situations. The measure of avoidance of difficult driving situations was used as a measure of self-regulation. Study participants were also asked about possible barriers to self-regulation of their driving.

In addition, participants completed a questionnaire about their medical conditions and medication use, completed questionnaires measuring depressed mood and anxiety, and were assessed on tests of various functional abilities previously found to be related to declines in the driving ability of older drivers (visual acuity, contrast sensitivity, visual field, head-neck flexibility, mental status, speed of information processing, visuospatial memory, and visual attention). The visual attention measure was developed specifically for this study and, consequently, was refined and assessed in two pilot studies (Chapter 5) and a subsequent validation study (Chapter 7). All of the other functional tests and questionnaires are described in Chapter 6. Finally, participants completed an on-road driving test, providing a measure of their driving ability (also described in Chapter 6).

The results for the driving practices questionnaire, the health questionnaire, functional testing, and on-road testing were compared in order to determine whether older drivers are capable of recognising their own impairments and adjusting for them with appropriate restrictions of their driving. First, the relationships between health and functional measures, and on-road driving performance were examined, in order to identify the best predictors of declines in driving ability among older drivers (Chapter 8). Secondly, responses on the questionnaire concerned with driving practices and beliefs were examined, in order to determine the extent to which self-regulation is practised by older drivers (Chapter 9). Thirdly, the relationships between self-regulation and the health, functional and on-road driving measures were analysed, in order to establish whether older drivers were self-regulating in accordance with their abilities (Chapter 10). A comprehensive analysis of this sort is unique in the road safety literature - no previous study has been conducted assessing all of these relationships within a single sample of older drivers. Finally, comparisons were made between the health and functional measures related to on-road driving ability and those related to self-regulation (Chapter 11). This allowed for an identification of the functional deficits that are associated with appropriate self-regulation (i.e. deficits associated with poorer driving ability but also with greater avoidance of difficult driving situations) and the types of deficits for which older drivers are *less* likely to compensate for by self-regulating (i.e. deficits associated with poorer driving ability but *not* with greater avoidance of difficult driving situations). No analysis of this sort has been undertaken in previous research into older drivers. The thesis concludes with a discussion of the implications of the findings for our knowledge regarding the driving abilities and practices of older drivers.

CHAPTER 5: PILOT TESTING OF A VISUAL ATTENTION MEASURE

5.1 Pilot Study One

5.1.1 Introduction

As part of a study of the relationship between older drivers' driving behaviour and functional abilities, it was decided to assess attentional abilities. This was based on a review of the literature on older drivers that revealed a number of findings linking age-related driving difficulties to age-related declines in attention (section 3.4).

A number of authors have postulated that deficits in visual attention may play a role in older drivers' crashes because attentional abilities have long been known to decline with age (e.g. Stankov, 1988) and because visual attention is required for many important driving tasks (e.g. Parasuraman & Nestor, 1991). Negotiating intersections is one such task, with the over-involvement of older drivers in intersection crashes being attributed by some authors to deficits in attention (e.g. Preusser et al., 1998).

Studies examining the attentional abilities of older drivers have found that declines in visual attention are linked to poorer on-road driving performance (e.g. Cushman, 1996) and greater crash involvement (e.g. De Raedt & Ponjaert-Kristoffersen, 2001). On the basis of these findings, it was decided that a measure of visual attention would be included in a battery of functional tests for the present study of older drivers.

One of the most commonly discussed tests that assesses the attentional abilities that are needed for driving is the Useful Field of View (UFOV) test (Owsley et al., 1998). The UFOV is a computerised test measuring speed of information processing, and selective and divided attention. It requires participants to detect the radial direction of a target presented in the visual periphery, in the presence or absence of visual distracters, while simultaneously performing a discrimination task presented in the centre of the visual field (Owsley et al., 1998).

Proponents of the UFOV test argue that it is a good test for screening older drivers because, in addition to identifying drivers with decreased visual fields, which have been related to driving difficulties (e.g. Johnson & Keltner, 1983), it also identifies those with attentional deficits. Studies of older drivers have related deficits in performance on the UFOV test both to crashes (e.g. Sims et al., 1998) and to on-road driving performance (e.g. Cushman, 1996). Moreover, deficits in UFOV performance have been found to be associated most strongly with crashes at intersections (Owsley et al., 1991).

In the light of the evidence, the UFOV is a good candidate test for assessing attention in the present study. There are, however, a few problems with this test. One is that most of the studies claiming that the UFOV test is highly predictive of crash involvement have been conducted by those responsible for the production and sale of the test itself (Ball & Owsley, 1991; Owsley et al., 1998; Owsley et al., 1991; Sims et al., 2000; Sims et al., 1998). Some independent large scale studies have failed to replicate these results (Brown et al., 1993; Hennessy, 1995). Another study attempted to use UFOV to predict driving performance in elderly adults and those with mild dementia but had to exclude the UFOV data because too many participants with mild cognitive impairment could not complete the test (Duchek et al., 1998). Anecdotal reports also suggest that many older people who have undertaken the UFOV test have found it unpleasant because they have to sit very close to a large computer screen (Professor P.F. Waller, University of Michigan Transportation Research Institute, personal communication, May, 2002). The test is also very expensive and requires special training to administer. A final problem with the test is that it does not incorporate any movement into the visual stimuli. Thus, although it successfully replicates the cluttered visual environment encountered when driving, there is none of the movement that also characterises the visual array presented to the driver of a moving vehicle.

Ideally, a test of visual attention would incorporate some elements of the UFOV test, including dual tasks, the use of central and peripheral vision, and a cluttered visual array but would not require participants to sit abnormally close to a screen and would also incorporate movement in the visual array. Therefore, it was decided to design a test that satisfied these requirements. Participants would be asked to simultaneously perform a central task and one requiring peripheral vision, and to detect targets in the periphery amid a visual array cluttered with moving, distracting stimuli.

The aim of the following two pilot studies was to undertake preliminary assessments and revisions of the tests that were designed to fulfil these requirements. While assessing these attention tests, the pilot studies also provided an opportunity to assess a driving attitudes and behaviour questionnaire that was also designed for use in a subsequent large-scale study of driver self-regulation. The pilot studies only used a small sample of participants and, consequently, only descriptive statistics are reported.

5.1.2 Method

5.1.2.1 Participants

Eight participants (four males and four females) aged over 70 years (*M*=74, *SD*=3.1) were recruited from the South Australian Genealogy and Heraldry Society, which is a community group that is generally staffed by elderly citizens. Only those over the age of 70 were approached to participate, in order to assess whether the tests were suitable for volunteers well over the minimum age for the full study (60 years old). This sample had completed an average of 15.4 years of education (*SD* = 1.6). None of the participants exhibited binocular Snellen visual acuity levels worse than 6/12 and all participants were fluent in English.

5.1.2.2 Materials

Participants were asked to complete a questionnaire, undertake a number of standard neuropsychological, physical and visual tests, and also a computer-administered test of visual attention which was designed for the purposes of the study. The neuropsychological, physical and visual tests were administered in order to gain practice in using these tests as preparation for their use in the main study, and to provide breaks between the computer-administered attention tests. This allowed participants to have breaks from looking at the computer screen. As the results for these other tests were not relevant to the pilot studies, the details of the tests will not be provided here. Similarly, the results of the questionnaire were not examined and so the details of the questionnaire will also not be provided here. These other measures will be described in the Methodology chapter (Chapter 6).

The visual attention test that was developed for the study was called the "Computerised Visual Attention Test" (CVAT) and consisted of a computer-administered series of reaction time tasks requiring divided and selective attention. There were two types of tasks: a primary task in the participants' central visual field and a secondary task in the participants' peripheral visual field. Participants were required to perform simultaneous detection of targets in central and peripheral vision (divided attention), with the speed of presentation of targets in the central task and the complexity of the visual array in the peripheral task (selective attention) both being manipulated. Both the central and peripheral tasks were presented within a single program that was run using Netscape Communicator 4.5, on a Hewlett Packard 71 computer and a 40 cm monitor.

Primary task. The primary (central) task on the CVAT involved responding to stimuli presented on the left hand third of the screen. The stimuli were large black letters (point size 80, Times New Roman) that were presented one at a time and that would change at one of two rates set by the investigator, with a new letter replacing the previous one every 700ms (fast) or 1400ms (slow). Participants were required to press the space bar on a standard keyboard with a finger on their left hand as soon as possible following the appearance of the letter X. After successfully detecting an X, a sound ('ding') was emitted from a speaker connected to the computer. There was random variation in the frequency of appearance of Xs but no letter 'X' was followed immediately by another X. On average, an X appeared once every six letters. All letters that would be most likely to be mistaken for an X at first glance (i.e. K, N, M, V, W, Y, Z) were removed from the set of characters used for this task. Reaction times for each X were recorded automatically to the nearest tenth of a second. Timing would cease two seconds after the presentation of an X, with reaction times greater than two seconds being counted as a miss. This length of time was chosen because the duration of the stimuli requiring detection in the secondary task (see below) was 2000ms. The primary task would end at the completion of the secondary task ,which ran concurrently. The random variation inherent in the frequency of Xs resulted in the number of Xs per primary task ranging between a minimum of 24 and a maximum of 41 for the slow rate of presentation, and between 57 and 75 for the fast rate of presentation.

Secondary task. The secondary (peripheral) task on the CVAT involved responding to the appearance of cars on the right hand two thirds of the screen. A simple picture of a car (see Figure 5.1) would appear in one of nine positions in a three by three matrix. The participant was required to respond by clicking the left mouse button with a finger on their right hand as soon as possible after detecting the presence of a car. Each car would remain on the screen for a duration of two seconds before disappearing, unless the participant successfully detected it, in which case it would disappear with the response, and a sound (‘ding’) would be emitted from a speaker connected to the computer. Again, reaction time was measured to the nearest tenth of a second and any reaction time greater than 2000ms was counted as a miss. For each set of trials, 27 cars would appear, three times in each location in the three by three matrix, varied randomly. The duration of time between the appearance of cars was either six, eight, ten, 12, or 14 seconds, and this was also varied randomly. This meant that the total time for each set of trials was approximately five minutes. If the participant responded in the absence of a target car, the reaction time to the next trial was discarded. In this way, false alarms could be recorded as well as correct detections. The measurement of false alarms was important because a high false alarm rate would indicate that participants were using a strategy of regularly responding even if they were not sure of the presence of a target, in order to minimise the possibility of missing targets.

Figure 5.1. Picture of a car used as a secondary task target stimulus in the CVAT

The secondary task (car detection) was performed in conjunction with the primary task (X-detection), thus providing a test of divided attention. The secondary task was assessed while the participant performed the primary task with a slow rate of presentation (a new letter every 1400ms) and also with a fast rate of presentation (a new letter every 700ms). These different speeds of the primary task provided two different levels of task complexity and thus, two conditions making varying demands on participants' divided attention capabilities. The primary task also ensured that the participants were engaged in a task in the centre of their vision that required constant monitoring, and therefore that the secondary task was performed using their peripheral vision. The fact that the task that appeared on the left side of the screen required a left-handed response and the task on the right side of the screen required a right-handed response should have aided initial learning of the dual task condition. It is known that tasks involving high compatibility between stimuli and responses are performed faster and are less vulnerable to interference from other tasks (Fitts, 1964).

The complexity of the secondary task was also manipulated by the presence or absence of visual distracters in the same area as the target cars. The visual distracters were simple black and white pictures of houses (see Figure 5.2) of a similar size and visual complexity as those of the cars. During the trials featuring the distracters, three of the nine positions in the three by three matrix were occupied by one of the houses. The three houses would move positions every two seconds. This provided a cluttered visual array in the periphery that also featured movement. By having the houses move every two seconds, the task could be run such that the appearance of a car always coincided with the movement of the houses. This meant that the simple cue of change (movement) in the periphery could not be used to detect the cars. This manipulation represented the selective attention component of the task - the ability to find a target (car) embedded in a complex visual array (houses). Participants had to perform the divided attention tasks at both levels of the speed of presentation of the primary task (fast and slow), and both with and without the visual distracters on the secondary task, giving a total of four subtests. A digital photograph of the computer screen during the subtest requiring both divided and selective attention is provided in Figure 5.3. Note in Figure 5.3 that the 'G' on the left side of the screen is a stimulus from the primary (X detection) task, while the car and the three houses on the remaining two thirds of the screen are stimuli from the secondary (car detection) task. The car to be detected in Figure 5.3 is in the middle of the three by three matrix. At this point of the subtest, the participant would be required to click the mouse to indicate detection of the car but would not be required to respond to the 'G'.

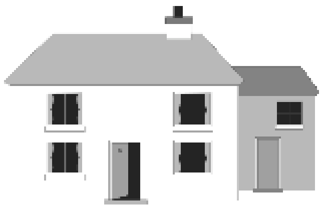

Figure 5.2. Picture of a house used as a secondary task distracter stimulus in the CVAT

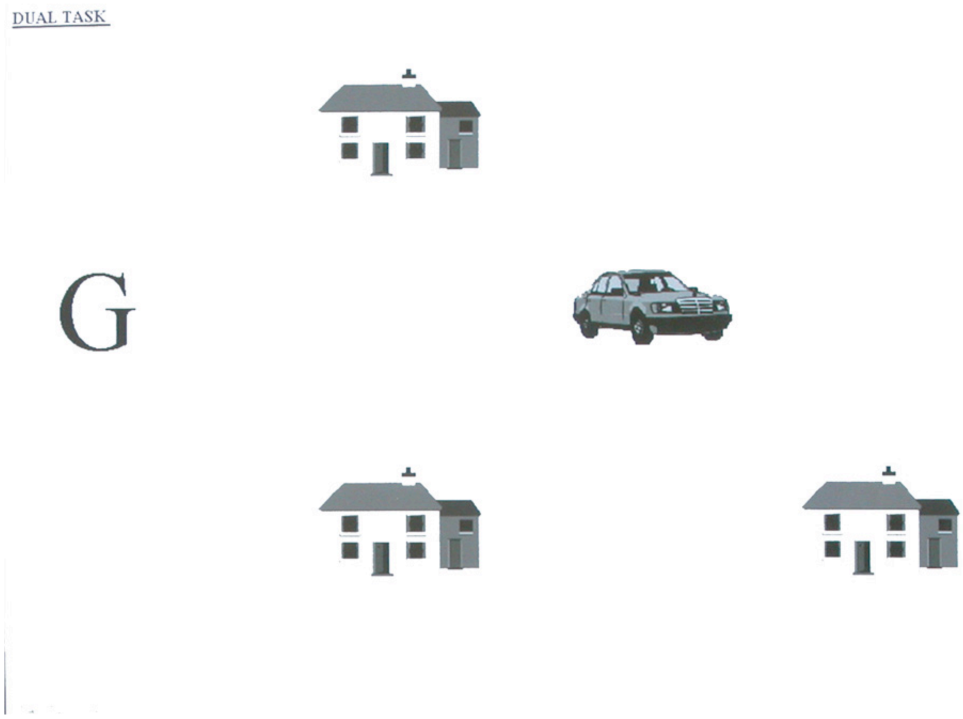

Figure 5.3. Digital photograph of the computer screen during a CVAT subtest requiring divided and selective attention.

In summary, the following four subtests on the CVAT were used to assess visual attention in the study:

Primary task *slow* condition, Secondary task *without* visual distracters. This subtest was designed to involve low demands on divided and selective attention.

Primary task *fast* condition, Secondary task *without* visual distracters. This subtest was designed to involve high demands on divided attention but low demands on selective attention.

Primary task *slow* condition, Secondary task *with* visual distracters. This subtest was designed to involve low demands on divided attention but high demands on selective attention.

Primary task *fast* condition, Secondary task *with* visual distracters. This subtest was designed to involve high demands on both divided and selective attention.

For each task (primary and secondary), performance was measured in terms of median reaction time, percentage of targets not detected, and the percentage of false alarms (responses in the absence of a target). For reaction time, it is customary to take the median as the measure of central tendency for each individual's scores because reaction time tasks tend to produce positively skewed distributions for which mean scores overestimate the typical response score (Tilley, 1996).

It was predicted that, if the CVAT was an appropriate measure of selective and divided attention, then performance on the secondary task (detection of cars) would be affected by the two manipulations of the task stimuli. First, secondary task performance would be worse in subtests involving a fast rate of presentation of stimuli on the primary task (greater divided attention load). Secondly, secondary task performance would be worse in subtests involving the presence of visual distracters on the secondary task (greater selective attention load).

5.1.2.3 Procedure

Participants were contacted by telephone and informed of the details of the study and what it involved. Those agreeing to participate were sent an appointment sheet, an information sheet (see Appendix 5A), a map of the University of Adelaide campus indicating where the assessment would take place, taxi vouchers enabling travel to and from the University, and a copy of the driving attitudes and behaviour questionnaire (see Chapter 6). Participants were requested to complete the questionnaire in their spare time and bring it with them to the testing session.

Upon arrival, participants were shown to the testing room. The information sheet was presented to the participants again to ensure that informed consent could be obtained. The participants then read and signed the consent form (refer to Appendix 5B). The researcher then asked to look at the driving attitudes and behaviour questionnaire that the participant had completed at home, and asked the participant if they had experienced any problems answering any of the questions.

This was followed by practice trials for the attention tasks. The general nature of the tasks was explained to participants before giving exact instructions for the primary task. Practice was then given for just that task, using the slow condition (letter every 1400ms) first and the fast condition (letter every 700ms) second. The instructions for the secondary task were then given and the participants were told that they would have to perform the two tasks at the same time. They were also told that they should concentrate the most on successful performance of the primary task. Practice was then given for the simultaneous performance of the primary and secondary tasks, using the slow rate of presentation of letters for the primary task and the no visual distracters condition for the secondary task. Next, the condition featuring visual distracters was explained and practice was given for performing the two tasks simultaneously using the slow rate of presentation of letters on the primary task, and the condition featuring the presence of visual distracters for the secondary task. Again, the need to concentrate the most on the primary task was emphasised. For all tasks, practice continued until the participants expressed comfort with the task (Verbatim instructions for the attention tests are provided in Appendix 5C.)

Having practiced all of the CVAT tasks, the participant commenced the experimental trials. Prior to their first subtest, they were told whether the letters would be changing at a fast or slow rate and whether the houses were appearing or not. They were also told that it would take approximately five minutes for the subtest to be completed. This information was provided to participants before starting each CVAT subtest.

The four CVAT subtests were not performed consecutively but were separated by a number of visual, neuropsychological and physical tests. On average, the four CVAT subtests, in addition to the other psychological, physical and visual tests, took approximately 1.5 hours to complete.

The four CVAT subtests were presented in four different orders, with each order being used for two of the eight participants. Participants would either perform the two subtests without visual distracters on the secondary task first, or the two versions with distracters first. Additionally, within each of these different orders, they would either do the primary task at a slow rate of presentation first, or at a fast rate of presentation first.

5.1.3 Results

5.1.3.1 Test Administration

Only one problem was identified with the CVAT testing procedure. During the first participant's performance of the CVAT, he often accidentally pressed the right mouse button in addition to the left one. This resulted in a browser menu appearing on the screen that could mask the appearance of targets and interfere considerably with task performance. A paper clip was then placed underneath the right button on the mouse, resulting in the right button being inactive without any interruption to the left button and without any damage being done to the mouse. There were no other problems with the administration of the CVAT and all participants reported finding the instructions for the tasks easy to understand.

5.1.3.2 CVAT Performance

The CVAT was assessed using a small sample of participants and so the results were analysed using only descriptive statistics. For reaction times, the results provided are group means of the median reaction times that were calculated for individual participants.

The results for the primary (X-detection) task are summarised in Table 5.1., with scores provided for detection failures, false alarms, and reaction times. The target detection failures are expressed as a percentage of the total number of targets presented, excluding targets not scored due to a preceding 'false alarm'. It can be seen that detection failures on the primary task were relatively rare, on average, although there was considerable variation. It also appears that there were slight increases in detection failures in the subtests involving a fast rate of presentation of targets and also in subtests involving the presence of visual distracters on the secondary task.

The results for false alarms (responses in the absence of targets) for the primary task are expressed as a percentage of the total number of targets presented. These results for false alarms were similar to those for detection failures. Again, rates were low overall with a slight increase for those subtests involving a fast rate of presentation on the primary task and for subtests featuring visual distracters on the secondary task.

Table 5.1 also shows that the pattern of results for the other measures of task performance (i.e. detection failures, false alarms) were repeated for median reaction time scores. Shorter reaction times were found for the primary task when there was a slow rate of presentation (i.e. slow Xs) and when there were no visual distracters on the secondary task (no houses).

Table 5.1
Percentage detection failures, percentage false alarms, and median reaction times for the primary (X-detection) task on the CVAT

Task Condition	% Detection failures		% False alarms		Median RT (ms)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Slow Xs, No Houses	2.5	3.5	0.6	1.7	480.0	35.8
Fast Xs, No Houses	4.2	7.3	1.7	1.3	502.5	41.3
Slow Xs, Houses	3.5	6.8	2.0	2.4	508.1	34.0
Fast Xs, Houses	4.7	4.8	2.9	2.3	522.5	47.5

Note. Slow or Fast Xs refers to the rate of presentation of stimuli on the primary task; Houses refers to the presence of visual distracters on the secondary task

Table 5.2 provides the detection failure percentages, false alarm percentages and median reaction times for the secondary task. Again, detection failures are expressed as a percentage of the total number of targets presented, excluding those targets preceded by false alarm responses. The number of targets missed was quite low for the secondary task, indicating that participants were good at detecting the cars, even when they were embedded within visual distracters. There does not appear to be any pattern in the results. This was inconsistent with the hypothesis that target detection on the secondary task would be worse with a faster rate of presentation of stimuli on the primary task and with the presence of distracters on the secondary task.

The percentages of false alarms for the secondary task represent the number of false alarms divided by the total number of targets presented, which was 27 for each condition. False alarms only occurred rarely for this task, with little discernible pattern in the results, except that there appeared to be a slightly higher likelihood of false alarms on the secondary task in subtests involving a fast rate of presentation on the primary task. The presence or absence of visual distracters on the secondary task did not appear to have affected the likelihood of false alarms. This was not consistent with the hypotheses.

Finally, Table 5.2 shows that there was a clear pattern of results for reaction times, with longer reaction times being recorded on the secondary task when it was performed in the presence of visual distracters. However, changes in the rate of presentation for the primary task did not markedly affect reaction times on the secondary task. The reaction times on the secondary task were, in fact, slightly longer for the slow rate of presentation condition on the primary task, although this difference was very small. The results are represented graphically in Figure 5.4, demonstrating the increase in reaction time in the presence of visual distracters. The longer reaction times for subtests involving visual distracters were consistent with expectations but the slightly longer reaction times with a slower rate of presentation for the primary task were not.

Table 5.2
Percentage detection failures, percentage false alarms, and median reaction times for the secondary (car detection) task on the CVAT

Task Condition	% Detection failures		% False alarms		Median RT (ms)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Slow Xs, No Houses	1.4	2.8	0.9	1.7	525.6	79.0
Fast Xs, No Houses	1.6	4.4	3.2	4.6	516.3	68.4
Slow Xs, Houses	3.5	5.6	1.4	3.9	646.3	70.2
Fast Xs, Houses	1.4	1.9	2.3	5.2	638.1	54.5

Note. Slow or Fast Xs refers to the rate of presentation of stimuli on the primary task; Houses refers to the presence of visual distracters on the secondary task

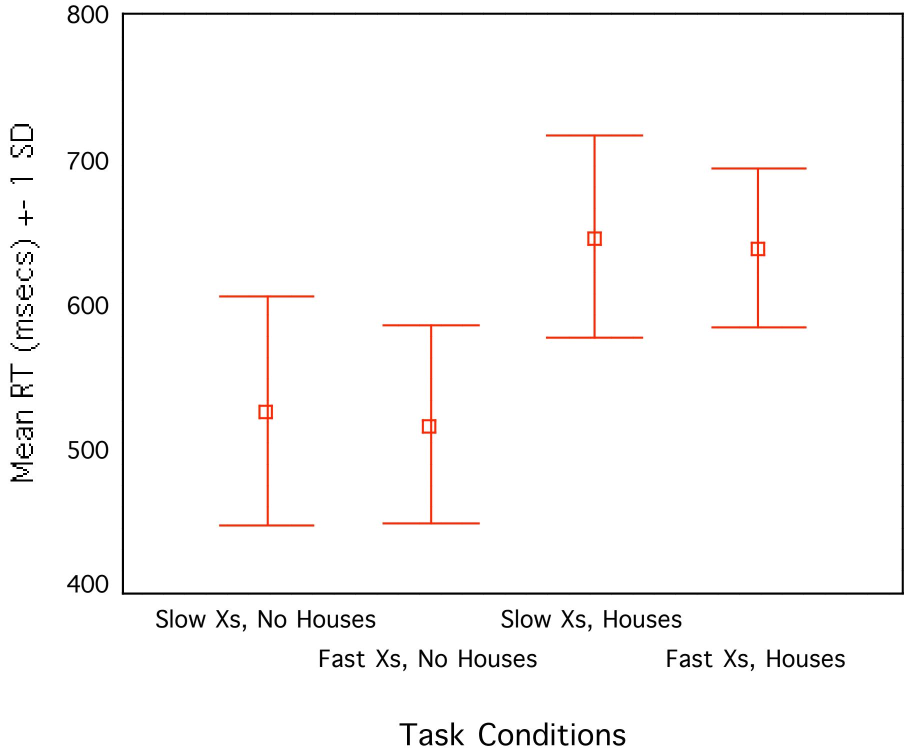

Figure 5.4. Median reaction times for the secondary task (car detection) on the Computerised Visual Attention Test, by task condition.

5.1.4 Discussion

The main aim of the first pilot study was to evaluate the suitability of the CVAT for measuring selective and divided attention. If the CVAT was appropriately designed, then performance on the secondary task (detection of cars) would be affected by two manipulations of the task stimuli. First, secondary task performance should be worse on subtests involving a fast rate of presentation of stimuli on the primary (X-detection) task (greater divided attention load). Secondly, secondary task performance should be worse on subtests involving the presence of visual distracters on the secondary task (greater selective attention load).

With respect to divided attention, there was limited evidence that increasing the rate of presentation of stimuli on the primary task, from a new letter every 1400ms to a new letter every 700ms, affected performance on the secondary task. There was no clear pattern for detection failures on the secondary task, with few targets undetected.

For false alarms (responding in the absence of a target) on the car detection task, there did appear to be an increase in the likelihood of false alarms when there was a fast rate of presentation on the primary task but, as with the detection failures, the percentages were low (less than four percent in all cases). Contrary to expectations, a faster rate of presentation on the primary task was associated with shorter reaction times on the secondary task, although the differences were not large. Therefore, there is limited evidence to suggest that altering the rate of presentation of stimuli on the primary task (X-detection) affected performance on the secondary task (car detection), indicating that it did not successfully test divided attention.

A possible reason for the failure to find the expected results on the test of divided attention was that participants were engaging in a trade-off between the two tasks, such that they were trying to maintain performance on the secondary task at the expense of performance on the primary task. When the results for the primary task were analysed according to the rate of presentation of the stimuli, they revealed that with a faster rate of presentation, there were small increases in detection failures, false alarms, and reaction times for the primary task. Although these increases were not large, they suggest that participants were not concentrating on maintaining performance on the primary task but, rather, were concentrating on successfully performing the secondary task and allowing deficits to appear in primary task performance. As a result, the usual divided attention pattern of deficits in secondary task performance, with increases in the complexity of the primary task, was absent.

With regard to selective attention, the results were more positive. Although there was little evidence of changes in detection failures and false alarms with the addition of visual distracters to the secondary task, there was a pronounced increase in reaction time. Reaction times increased by over 20 percent when visual distracters were present, indicating that a cluttered visual array negatively affected participants' abilities to quickly detect the target stimuli. This effect occurred despite evidence that participants were allowing primary task performance to be affected by the additional demands of the secondary task. When the secondary task was performed in the presence of visual distracters, there were small increases in detection failures, false alarms and reaction times on the primary task.

Finally, false alarms for both the primary and secondary tasks were rare. This suggests that, for both tasks, participants were only responding when they thought that targets were present, rather than using high response strategies to minimise target detection failures.

The results, overall, indicate that participants were giving priority to performance on the secondary task rather than the primary task. This resulted in performance on the secondary task not being affected negatively by increases in difficulty of the primary task. Therefore, the CVAT used in the first pilot study proved inadequate for present purposes, making it necessary to alter the CVAT so that greater difficulty associated with the primary task was accompanied by deficits in performance on the secondary task. One successful component of the tasks, however, was the selective attention component. The presence of visual distracters in the periphery clearly affected performance on the secondary task.

As a result of this first pilot study, the CVAT was altered to increase the likelihood that a manipulation of the difficulty level of the primary task affected secondary task performance, and a second pilot study was conducted.

5.2 Pilot Study Two

5.2.1 Introduction

It was decided that a small number of alterations would be made to the CVAT and the instructions given to participants, in order to provide a better assessment of divided attention. The changes were designed to encourage participants to use only their peripheral vision for the secondary task and to direct more attention to the primary task.

One of the most notable changes to the testing procedure was the introduction of measures of single task performance. In the first pilot study, the complexity of the divided attention task was only varied by presenting the stimuli in the primary task at two different rates. In the second pilot study, divided attention would be assessed using the more traditional method of comparing results on tasks performed separately with results on the tasks performed concurrently. Specifically, participants would perform the primary task by itself, using the two different rates of letter presentation. Participants would also perform the secondary task by itself, in both the condition without visual distracters (no houses) and the condition with visual distracters (houses). These four subtests were added to the four used in the first pilot study.

Changes were also introduced to the instructions that were given to participants. Whereas in the first pilot study participants were merely told that reacting to the Xs in the primary task was the most important part of the test and that they should try not to miss any Xs, in the second pilot study, participants were given more explicit instructions regarding the importance of the primary task. Specifically, participants were told to focus their eyes on the letters (the stimuli used for the primary X-detection task) for the duration of the test, so that the cars appearing on the right side of the screen were only in their peripheral vision. This instruction to focus their eyes on the letters was then followed by the instructions from the first pilot study that the X detection task was the most important and that they should make sure they detect all the Xs. The instruction to always focus their eyes on the letters was repeated prior to each subtest involving a secondary task (car detection). When participants were performing the secondary task by itself, the letters (the stimuli used for the primary X-detection task) kept appearing on the screen even though participants did not have to react to them. Despite not having to react to the letters, the participants were instructed again to focus their eyes on the letters for the duration of the test, so that the cars were still kept in their peripheral vision only. Thus, the secondary task always required the use of peripheral vision, and any decrements in performance on the secondary task associated with the additional load of the concurrent primary task would be due solely to the requirement of division of attention, rather than to differences in where the participants were fixating their eyes.

Another alteration to the task was that a sound was no longer used to reward successful detection but to signal detection failures. In the first pilot study, whenever a participant responded correctly to an X or a car, a sound ('ding') was emitted by the computer. However, if participants failed to detect an X, they would be unaware of it and would, therefore, be given no negative feedback suggesting that they refocus their attention on the primary task. In the set-up used for the second pilot study, sounds accompanying successful responses to Xs and cars were removed, while a sound ('ding') was emitted by the computer two seconds after the appearance of any X not eliciting a response from the participant. This meant that participants who failed to detect an X in the primary task heard a sound alerting them to the fact. This sound was designed to discourage the participants from allowing their attention to shift from the primary task. No sounds were used for the secondary task. Due to the fact that failures to detect an X would result in a sound being produced, the primary task was altered so that no sound would be produced while an X was on the screen. As the sound occurred 2000ms after the first appearance of an X, the task was changed so that neither of the two letters following an X would be an X. This meant that in the fast rate of presentation condition (a new letter every 700ms), the next X could not appear until 2100ms (3x700ms) after the appearance of the preceding X. During practice of the tasks, participants were shown the way in which failure to detect an X resulted in the production of the sound two seconds after the appearance of the X.

5.2.2 Method

5.2.2.1 Participants

Eight participants (five males and three females) aged from 60 to 65 (M = 62.6, SD = 1.9) were recruited from the South Australian Genealogy and Heraldry Society. As the first pilot study had demonstrated that the design of the CVAT was suitable for those aged over 70, the second pilot study was conducted without the requirement that participants be aged 70 or above. This sample had completed an average of 12.8 years of education (SD = 2.7). None of the participants exhibited binocular Snellen visual acuity levels worse than 6/12 and all participants were fluent in English.

5.2.2.2 Materials

Participants were asked to undertake a number of standard neuropsychological and vision tests, and also the CVAT designed for the purposes of this study. The questionnaire pilot tested in the first pilot study was not given to the participants in the second pilot study.

The neuropsychological and vision tests were administered for the sole purpose of providing breaks between the CVAT subtests that were the focus of this pilot study. For this reason, they are not described here and the results for these tests are not included.

The CVAT used in the second pilot study was the same as that in the first pilot study (see section 5.1.2.2 Materials) except for the changes described in the Introduction for this second pilot study (section 5.2.1). This meant that there were eight different CVAT subtests used in the second pilot study and these are described below (note that the term "simple attention" is used hereafter to allow differentiation from selective and divided attention):

Primary Task Only (Slow Condition): This subtest was designed to measure low demand simple attention for central vision.

Primary Task Only (Fast Condition): This subtest was designed to measure high demand simple attention for central vision.

Secondary Task Only (Without Visual Distracters): This subtest was designed to measure simple attention for peripheral vision.

Secondary Task Only (With Visual Distracters): This subtest was designed to measure selective attention for peripheral vision.

Primary Task (Slow Condition) and Secondary Task (Without Visual Distracters): This subtest was designed to measure low demand divided attention.

Primary Task (Fast Condition) and Secondary Task (Without Visual Distracters): This subtest was designed to measure high demand divided attention.

Primary Task (Slow Condition) and Secondary Task (With Visual Distracters): This subtest was designed to measure low demand divided attention, and selective attention for peripheral vision.

Primary Task (Fast Condition) and Secondary Task (With Visual Distracters): This subtest was designed to measure high demand divided attention, and selective attention for peripheral vision.

5.2.2.3 Procedure

The manner of recruitment of participants and obtaining consent were identical to the first pilot study (see section 5.1.2.3) except that a different information sheet was used (see Appendix 5D).

After obtaining consent, participants began practice trials for the CVAT. The general nature of the tasks was explained to participants before exact instructions were given for the primary task. Practice was then given for just that task, using the slow condition (letter every 1400ms) first and the fast condition (letter every 700ms) second. When participants were comfortable with the task of detecting the Xs, they were told to let an X go by without reacting to it, so that they could hear the sound accompanying a detection failure. It was explained to them that they would hear this sound whenever they failed to detect an X. The instructions for the secondary task were then given and the participants were told that they would have to perform the two tasks at the same time. They were also told that they must always keep their eyes focussed on the letters, so that the cars were appearing in their peripheral vision only. Practice was then given for the simultaneous performance of the primary and secondary tasks, using the slow rate of presentation of letters for the primary task and the no visual distracters condition for the secondary task. Next, the condition featuring visual distracters was explained and practice was given for performing the two tasks simultaneously using the slow rate of presentation of letters on the primary task, and the condition featuring the presence of visual distracters for the secondary task. Again, the need to focus their eyes the entire time on the letters was emphasised. For all tasks, practice continued until the participants expressed comfort with the task (Verbatim instructions for the attention tests are provided in Appendix 5E.)

Having had practice at all the tasks of the CVAT, the participant was told that it was time to do the first CVAT subtest. They were told whether they would have to react to just the Xs, just the cars, or both Xs and cars. They were then told, where appropriate, whether the letters would be changing at a fast or slow rate and whether the houses would be appearing with the cars or not. They were also told that it would take approximately five minutes for the task to be completed.

Again, although there were only eight participants performing eight attention tests, an attempt was made to balance the order of the tests. Eight different orders of the tasks were chosen and these different orders meant that participants were equally as likely to have to perform the single tasks before the dual tasks and vice versa, to perform tasks with a slow rate of presentation of the letters before those with a fast rate and vice versa, and to perform tasks featuring visual distracters before those without distracters and vice versa (see Appendix 5F for details).

Participants were asked to perform the eight CVAT subtests in four blocks of two subtests each, separated by a number of neuropsychological and vision tests. In total, the procedure took approximately two hours to complete.

5.2.3 Results

As with the first pilot study, measures of detection failures (percentage of targets not responded to), false alarms (percentages of targets preceded by a response when no target was present), and median reaction time for successful detection trials were recorded for each task in each condition. Comparisons across the two pilot studies revealed that the participants in the second pilot study made less errors (target detection failures and false alarms) and recorded shorter reaction times, on average, than those in the first pilot study. This is likely to be due to the younger average age of those in the second pilot study. However, the important aspect of the results is not the magnitude of errors and reaction times but the pattern of results across the different CVAT subtests.

The results for detection failures, false alarms and reaction times on the primary task are shown in Table 5.3. The detection failures are again expressed as a percentage of the total number of targets presented, not including targets not scored due to a preceding ‘false alarm’. The clear pattern of these results is that there was a higher likelihood of participants failing to detect targets when the stimuli to be detected were presented at a fast rate of presentation, and a small increase in this likelihood when the concurrent car detection task was being performed in the presence of visual distracters. It was also the case that detection failures were rare, with the highest average percentage of targets being missed for any of the subtests being just over three percent. These results mirror those of the first pilot study (see Table 5.1).

False alarms (responding in the absence of a target) on the primary task are again expressed as a percentage of the total number of targets presented. These results for false alarms followed a similar pattern to those for detection failures. False alarm rates were low overall, with the highest percentage of false alarms for any subtest being less than three percent. There was an increase in false alarms for the dual task compared to the single task subtests, and an increase for subtests involving a fast rate of presentation on the primary task.

Table 5.3 shows that there was little difference in primary task reaction times except for an increase in those subtests requiring the simultaneous detection of targets in the secondary task in the presence of visual distracters. There was neither an effect of the rate of presentation of the Xs, nor of the secondary task without visual distracters.

Table 5.3
Percentage detection failures, percentage false alarms, and median reaction times for the primary (X-detection) task on the CVAT

Task Condition	% Detection failures		% False alarms		Median RT (ms)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Single Task						
Slow Xs Only	0.00	0.00	0.00	0.00	463.3	55.5
Fast Xs Only	0.19	0.54	0.61	1.45	423.8	38.2
Dual Task						
Slow Xs, No Houses	0.00	0.00	1.61	1.74	426.9	36.9
Fast Xs, No Houses	0.63	0.87	2.32	1.50	435.0	42.2
Slow Xs, Houses	1.19	2.38	1.20	1.65	468.1	28.3
Fast Xs, Houses	3.06	3.66	2.92	1.44	465.6	45.8

Note. Slow or Fast Xs refers to the rate of presentation of stimuli on the primary task; Houses refers to the presence of visual distracters on the secondary task

Table 5.4 provides the target detection failure percentages, false alarm percentages and reaction times for the secondary task. Again, target detection failures are expressed as a percentage of the total number of targets presented, excluding those targets preceded by false alarm responses. Very few targets were missed on the secondary task but those that were missed all appeared in the presence of visual distracters.

The percentages of false alarms for the secondary task represent the number of false alarms divided by the total number of targets presented, which was 27 for each condition. False alarms only occurred rarely for the secondary task, with little discernible pattern in the results.

Table 5.4 shows that reaction times were longer when the secondary task had to be performed in the presence of visual distracters, as was found in the first pilot study (see Table 5.2). However, the results also reveal that participants had longer reaction times when performing the secondary task in the dual task situation compared to performing the task by itself. This can be seen by comparing the reaction time for the No Xs, No Houses condition with those for the Slow Xs, No Houses and Fast Xs, No Houses conditions, and by comparing the reaction time for the No Xs, Houses condition with those for the Slow Xs, Houses and Fast Xs, Houses conditions. With regard to rate of presentation of the stimuli used for the primary (X-detection) task, there was no pattern in the results to indicate a clear and consistent effect of this variable on secondary task reaction time. Therefore, it appears that performance on the secondary task was affected by the single task/dual task manipulation and the absence/presence of visual distracters manipulation but not by the manipulation of the rate of presentation of the stimuli used for the primary task. The mean reaction time scores for the secondary task in the second pilot study are presented graphically in Figure 5.5, where it can be seen that reaction times were greater in the presence of visual distracters and, to a lesser degree, in the dual task conditions.

Table 5.4

Percentage detection failures, percentage false alarms, and median reaction times for the secondary (car detection) task on the CVAT

Task Condition	% Detection failures		% False alarms		Median RT (ms)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Single Task						
No Xs, No Houses	0.00	0.00	0.00	0.00	422.5	50.1
No Xs, Houses	0.46	1.31	0.00	0.00	513.8	50.4
Dual Task						
Slow Xs, No Houses	0.00	0.00	0.46	1.31	467.5	45.3
Fast Xs, No Houses	0.00	0.00	0.00	0.00	460.0	33.4
Slow Xs, Houses	1.39	2.76	0.00	0.00	573.1	72.3
Fast Xs, Houses	0.93	2.62	0.93	1.71	595.0	64.8

Note. Slow or Fast Xs refers to the rate of presentation of stimuli on the primary task; Houses refers to the presence of visual distracters on the secondary task

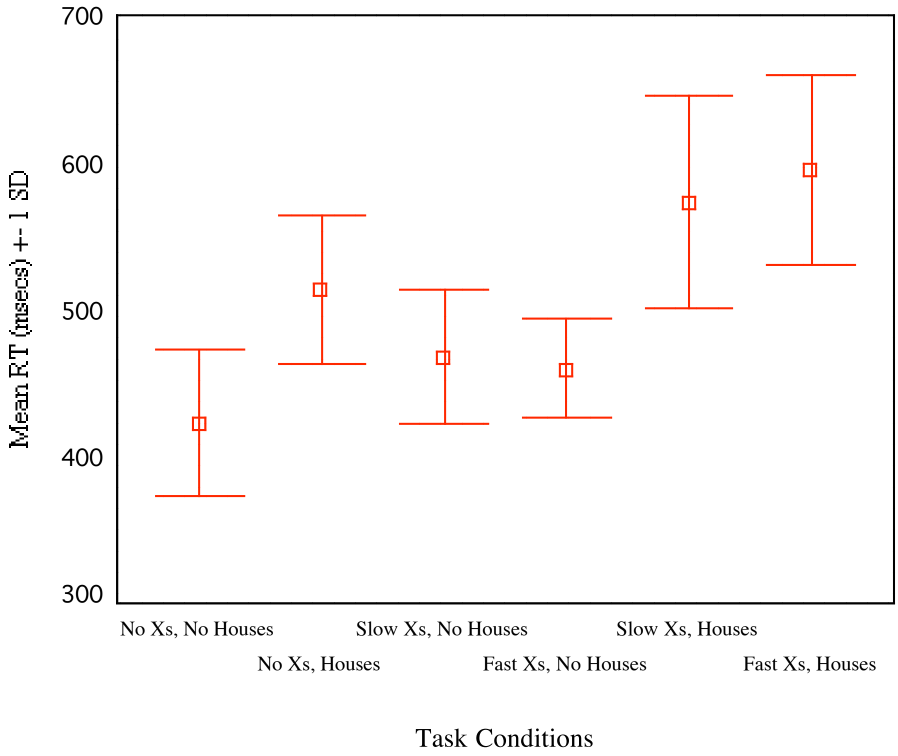

Figure 5.5. Median reaction times for the secondary task (car detection) on the Computerised Visual Attention Test, by task condition

5.2.4 Discussion

The purpose of the second pilot study was to improve upon the computer-based reaction time tasks that were used to assess divided and selective attention. Specifically, it was undertaken to see whether performing the two component tasks of the CVAT (X-detection and car detection) separately and concurrently would reveal decrements in performance on the secondary task (car detection) in the dual task condition. The second pilot study also provided an opportunity to confirm that the manipulation of the rate of presentation of stimuli on the primary task would have no consistent effect on performance on the secondary task, and to confirm that the visual distracters would cause decrements in performance on the car detection task, consistent with a manipulation of selective attention.

With regard to the dual task manipulation, the results clearly showed that there were increases in reaction time on the secondary (car detection) task when it was performed concurrently with the primary (X-detection) task compared with when it was performed by itself. This indicates that the dual task manipulation used in the CVAT in the second pilot study was a successful method of assessing divided attention.

Originally, the different rates of presentation of the stimuli used on the primary task were meant to create different levels of divided attention requirements affecting secondary task performance but the first pilot study found that changes to the rate of presentation had no consistent effect. This was confirmed in the second pilot study, with no consistent pattern of differences between reaction time scores on the secondary task according to the rate of presentation of items on the primary task. It is also noteworthy that reaction time scores also did not differ on the primary task according to rate of presentation of the stimuli, although there were small increases in the likelihood of detection failures and false alarms for the subtests featuring a fast rate of presentation.

Also confirmed in the second pilot study was the effect of the visual distracters (houses) on secondary (car detection) task performance. When the secondary task had to be performed in the presence of visual distracters, there were increases in both detection failures and reaction time. This suggests that the visual distracters are a useful method of altering selective attention requirements. It is also worth noting that the selective attention manipulation affected performance on the primary task, with small increases in detection failures and reaction time, consistent with participants having to concentrate harder on the secondary task when it was more difficult. Despite this extra concentration on the secondary task suggested by the small decrements in primary task performance, the effects of this manipulation on secondary task performance were still very clear.

Finally, false alarms (responding in the absence of a target) were rare for both the primary and secondary tasks in the second pilot study. This confirms a finding of the first pilot study that participants respond only when they think that a target (either an X or a car) is present, rather than adopting a high response strategy to try and minimise target detection failures while accepting a higher false alarm rate.

5.3 Conclusion

As a result of the two pilot studies, it was decided that the two tasks of the CVAT (X-detection and car detection) represented a useful method of assessing divided and selective attention. For the main study, participants would be asked to perform the two component tasks separately and concurrently, to assess the effects of divided attention, and would also be asked, in each case, to perform the secondary (car detection) task both with and without the presence of visual distracters (houses), in order to assess the effects of selective attention. The manipulation of the rate of presentation of items on the primary task would not be included in the main study as it was shown in both pilot studies to have no effect on secondary task performance. Scores derived from the CVAT would include measures of both speed and accuracy. The speed measure for each task would be reaction time while the accuracy measure would be target detection failures. False alarms would not be analysed as the number of these in both pilot studies was very low, indicating that participants tend not to use response strategies resulting in high false alarm rates.

In conclusion, the CVAT in the main study would consist of five different subtests. Measurements of target detection and reaction time would be obtained for each of these five subtests, with different levels of target complexity defined in terms of different levels of divided and selective attention. These five different CVAT subtests are as follows:

- primary (X-detection) task only (measure of simple attention in central vision)
- secondary (car detection) task only, without visual distracters (houses) (measure of simple attention in peripheral vision)
- secondary task only with visual distracters (measure of selective attention in peripheral vision)
- dual tasks without visual distracters on the secondary task (divided attention, central and peripheral vision)
- dual tasks with visual distracters on the secondary task (divided and selective attention, central and peripheral vision)

CHAPTER 6: METHODOLOGY

6.1 Introduction

This chapter provides details of the methods used for two studies. The main study was concerned with an examination of the self-regulatory practices of older drivers (Chapters 8-10). This study required a group of older drivers to complete a questionnaire concerned with their driving behaviour and attitudes, together with a series of functional tests, and an on-road driving test. The other study (Chapter 7) was concerned with validating the visual attention measure (Computerised Visual Attention Test - CVAT), which was developed for use in the self-regulation study. The validation study examined the CVAT's test-retest reliability by assessing a sub-sample of drivers from the self-regulation study on the CVAT on a second occasion, and examined the CVAT's construct and predictive validity by additionally assessing the same sub-sample of drivers on a series of commonly used standard tests of attention. The methodology for the main study on self-regulation is described in section 6.2, followed by the methodology for the validation study in section 6.3.

6.2 Study One: Self Regulation

6.2.1 Participants

A group of 104 older drivers (aged 60 years or more) was recruited from two sources: the general community (*n* = 93) and the client pool of the Driver Assessment Rehabilitation Service (DARS) at the University of South Australia (*n* = 11). Those from the general community were recruited through Senior Citizens clubs and Australian Retired Persons Association clubs in metropolitan Adelaide. The drivers from the DARS client pool were referred, mostly by general practitioners, for an assessment of their ability to drive and, hence, their right to continue to hold a driver's licence. Participants were recruited from both the general community and DARS in order to sample a wide range of driving abilities.

The total sample consisted of 65 females and 39 males, and their ages ranged from 60 to 92, with a mean of 74.2 (*SD* = 6.3). The number of years of formal education of the sample ranged from six to 21, with a mean of 10.9 (*SD* = 3.0). Their IQ scores, as estimated from the Wechsler Test of Adult Reading (Wechsler, 2001) using the American standardisation sample, ranged from 85 to 126, with a mean of 108.6 (*SD* = 9.4).[2]

All participants were required to be fluent in English, to be in possession of a full driver's licence (i.e. at least Class C, able to drive non-commercial motor vehicles not exceeding 4,500kg), and to have been driving for over ten years. The latter requirement was imposed to ensure that the driving behaviour of participants was not influenced by inexperience. Another requirement was that no participant had suffered a cerebrovascular accident (stroke), traumatic brain injury, or other event causing a sudden loss of functioning, in the past year. The reason for this is that such events lead to a compulsory suspension of the person's licence and such alterations to driving behaviour are externally imposed rather than reflecting voluntary changes.

6.2.2 Materials

The materials for the study included a questionnaire measuring self-reported health and driving attitudes and behaviour; a number of visual, physical, psychological and neuropsychological tests (hereafter referred to as "functional tests"); and an on-road driving test.

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[2] The participants from the referral group were not found to differ significantly from the general community participants in terms of years of education or IQ, but were found to have a higher mean age (*M*=79.1, *SD*=5.6 versus *M* = 73.7, *SD* = 6.2, $t(102) = -2.8$, $p = .006$).

6.2.2.1 Questionnaire

The questionnaire used in the study was the Driver Mobility Questionnaire, which consisted of 72 questions and was divided into three sections (refer to Appendix 6A for the complete questionnaire). The first section of the questionnaire asked for the participants' age, gender, and whether they had held a drivers' licence for more than ten years.

The next section contained 16 questions relating to medical conditions and medications. Participants were provided with a list of 14 medical conditions in this section and asked to indicate whether they suffered from each condition or not. The 14 conditions were chosen because they were likely to compromise driving ability. Additionally, participants were asked to name any other conditions they had that were not on the list. For each condition that they nominated, participants were asked to indicate on a three point scale how much they thought it affected their everyday functioning. A health scale of this nature has previously been used by Steinberg et al. (1994) and in a road safety context by Stalvey and Owsley (2000). The self-ratings of the extent to which medical conditions affected everyday functioning were summed for each participant to give an index of general health. Participants were also asked to list the medications they took more often than once a month. In order to classify medications according to whether they were potentially hazardous to driving, details of the medications were obtained from the Monthly Index of Medical Specialities (MIMS) annual published in 2000 (MIMS Australia, 2000). The MIMS annual is a publication providing details about currently available prescription and non-prescription medications, including likely and possible side-effects. All medications described as commonly causing drowsiness, dizziness, or disturbance of central nervous system functioning were classified as being "potentially hazardous to driving".

The third section of the Driver Mobility Questionnaire was a combination of selected questions from the Driving Habits Questionnaire (DHQ) used by Owsley et al. (1999) and the Driver Perceptions and Practices Questionnaire used by Stalvey and Owsley (2000). The questions taken from the DHQ included those concerned with current driving, driving exposure (amount of driving done per week), driving confidence (plus supplementary questions about avoidance of driving used by Stalvey and Owsley), crashes and citations, and driving space (the geographical area over which driving is done). Questions taken from the Driver Perceptions and Practices Questionnaire included those concerned with perceived barriers to self-regulation and regulatory self-efficacy. However, a number of questions were altered to provide additional information or to adjust them for a South Australian, rather than American, context. The details of the adjustments that were made to the original source questionnaires are provided in Appendix 6B.

The self-ratings variables (driving ability, vision, dual task ability) were all scored on five point scales from 1 = poor to 5 = excellent. The driving exposure variables derived from the Driver Mobility Questionnaire included the number of days driven per week, the number of trips taken per week, and the number of kilometres driven per week. For driving confidence, participants had to rate their confidence in nine difficult driving situations (e.g. driving in the rain) on five point scales, with 1 = not at all confident and 5 = completely confident. These ratings were summed to create an overall confidence score ranging from 9 (not confident at all in any difficult driving situation) to 45 (completely confident in all driving situations). “Driving space” (the geographical area in which driving is done) was based on whether participants drove in five particular areas (e.g. local neighbourhood, interstate), with one point awarded for each area they drove in, giving a maximum score of five (indicative of driving in all areas). Avoidance of difficult driving situations was based on the same nine driving situations as the driving confidence measure. Participants had to report their level of avoidance for each situation on a five point scale from 1 = never avoid to 5 = always avoid. These ratings were summed to create an overall avoidance score ranging from 9 (never avoid any driving situations) to 45 (always avoid all difficult driving situations). For perceived barriers of self-regulation, participants had to indicate whether they strongly agreed, agreed, disagreed or strongly disagreed that each of six factors (e.g. unavailability of public transport) stopped them from changing when and where they drove. Scores on a four point scale for each factor (strongly agree = 4, strongly disagree = 1) were summed to produce an overall score ranging from 6 (no barriers to self-regulation) to 24 (many barriers to self-regulation). Finally, regulatory self-efficacy was assessed by asking participants how hard they would find it to avoid each of eight difficult driving situations (e.g. rain). Responses of 'very hard' were given one point, 'somewhat hard' given two points and 'not hard at all' given three points. The sums of these scores gave an overall self-efficacy score ranging from 8 (low self-efficacy) to 24 (high self-efficacy).

Four of the questions asked participants about their crash and traffic violation records in the previous five years (i.e. number of crashes, number of police-reported crashes, number of traffic violations, number of times pulled over by the police). In order to check their responses concerning crashes on official databases, participants were asked to provide their driver's licence numbers. These licence numbers were then used to search the Traffic Accident Reporting System (TARS) database for crashes in the previous five years.

Participants were also asked questions about their preferred mode of travel, whether they wear glasses when driving, how their usual driving speed compares with other traffic, whether anyone had ever suggested to them that they cease or limit their driving (and if so, whom), who they thought was the best person to make decisions regarding driving cessation, and whether they had reduced their driving in the previous ten years (and if so, why). The DMQ measures concerned with driver beliefs and behaviour that were used in the study are summarised in Table 6.1.

Table 6.1
Driver attitude and driving behaviour measures in the Driver Mobility Questionnaire

Measure	Question numbers	Range of scores
Preferred mode of travel	1	NA
Wear glasses	2	NA
Relative speed of driving	3	1 - 5
Suggestions to limit driving	4	NA
Self-ratings		
Of driving ability	5	1 - 5
Of vision	6	1 - 5
Of dual task ability	7	1 - 5
Best person to decide on cessation	8	1 - 4
Driving exposure		
Days driven per week	9	0 - 7
Trips taken per week	10	min of zero
Kilometres driven per week	11	min of zero
Reductions in driving	12	NA
Driving confidence		
In specific driving situations	13 - 21	1 - 5
Overall		9 - 45
Crashes and citations	22 - 25	min of zero
Driving space	26 - 30	0 - 5
Driving avoidance		
In specific driving situations	31 - 39	1 - 5
Overall		9 - 45
Perceived barriers to self-regulation		
For specific barriers	40 - 45	1 - 4
Overall		6 - 24
Regulatory self-efficacy		
In specific situations	46 - 53	1 - 3
Overall		8 - 24

Note: NA = not applicable, a categorical variable; min of zero = minimum of zero

6.2.2.2 Functional Measures

Participants completed a number of functional measures. The measures were as follows:

Geriatric Depression Scale (Brink et al., 1982). This is a 30-item questionnaire that assesses the presence of depressive symptoms and was designed specifically for use with elderly populations. Each item requires a yes/no response (sample question: "Do you frequently feel like crying?"). Scores range from 0 to 30, with higher scores indicating a higher level of depressive symptoms. The scale is suitable for older adults because it has few somatic items that could artificially inflate the scores of persons in older age groups.

State-Trait Anxiety Inventory (Speilberger, 1983). This is a two part questionnaire assessing state anxiety (current level of anxiety) and trait anxiety (usual level of anxiety). Both parts consist of 20 items, each of which is a statement related to anxiety (e.g. "I feel relaxed") requiring a response on a four point scale. In the state anxiety section, the participant must indicate how much their feelings are the same as those expressed in the item ("not at all" to "very much so"). In the trait anxiety section, the participant must indicate how often they experience what is expressed in the item ("almost never" to "almost always"). Scores for each scale range from 20 to 80, with a higher score indicating higher levels of anxiety.

Snellen Static Visual Acuity. Static visual acuity was measured for each eye separately, and also binocularly, using a Snellen wall chart (black letters on a white background) adjusted for a viewing distance of 3m. The rows of letters on the chart correspond to visual acuity levels of 6/60 (i.e. person able to read at 6m what an average person is able to read at 60m), 6/36, 6/24, 6/18, 6/12, 6/9, 6/6 and 6/5. The smallest line for which the participant was able to read over half of the letters was recorded as their visual acuity level, with higher scores reflecting poorer visual acuity. As monocular vision measures have been found to be of importance for driving studies (Ivers et al., 1999), both binocular and monocular scores were used in the analyses.

Pelli-Robson Contrast Sensitivity (Pelli et al., 1988). This test involves a wall chart displaying letters of a constant size but varying levels of contrast with the background. The letters are arranged in sets of three and each set of letters is of a lower contrast level than the preceding set. The chart is read at a distance of 1m, first with each eye separately and then binocularly. For each condition, the participant's contrast sensitivity level is the log of the lowest contrast level for which the participant is able to correctly identify two of the three letters in a set. The chart provides scores ranging from zero to 2.25, with higher scores corresponding to better contrast sensitivity. As for visual acuity, both binocular and monocular scores were used in the analyses.

Each participant's *visual field* was measured using a simple procedure, which involved holding up a small object at a distance of one metre in the participant's peripheral visual field and asking if he or she could see it. A black rectangular object (13 x 3 cm) was chosen as the visual target, for its strong contrast with the white walls of the testing room. The participant was asked to stare at a small marker on the wall directly in front of him or her and the object was moved closer to the participant's central field of view at 10 degree intervals until he or she could see it. This was repeated for both the left and right sides of the participant's visual field. The greatest angle, with a maximum of 90 degrees, at which the participant could see the object was recorded for both the left and right side visual fields. This procedure was similar to one used in a previous study (Marottoli et al., 1998) that found a significant relationship between visual field and adverse driving events.

Neck mobility was assessed with a goniometer (supplied by Mentone Educational Centre, Victoria, Australia). This device was attached to the participant's seat in the testing room and was lowered to a position slightly above the participant's head. The participant was then asked to look straight ahead and the goniometer was set at zero degrees. The participant was then requested to turn his or her head horizontally to the left and then the right as far as possible, while keeping his or her shoulders straight. The angles of left and right neck rotation, to the nearest ten degrees, were measured and recorded. Higher scores reflect better neck mobility.

The *Modified Mini-Mental State Examination (3MS)* (Teng & Chui, 1987). This test is an updated version of the Mini Mental State Examination (Folstein et al., 1975) and measures basic cognitive functioning. It assesses basic abilities in a number of cognitive domains, including mental reversal, recall, temporal and spatial orientation, verbal fluency and speech production. Possible scores for the 3MS range from zero to 100. It is also possible to calculate a score out of 30, corresponding to the score the participant would have achieved for the original Mini Mental State Examination, for which a cut-off of 24 is standard for suspected dementia (Lezak, 1995). For comparison purposes, both scores out of 30 and 100 were used in the analyses.

Wechsler Test of Adult Reading (Wechsler, 2001). This test was used to provide an estimate of intellectual ability (IQ). It assesses word pronunciation and involves participants reading aloud a list of 50 words with irregular spellings that are presented on a card. A point is awarded for each word correctly pronounced, producing a score out of 50, which was then converted to a standard IQ score using age stratified norms, based on an American sample.

Symbol Digit Modalities Test (Smith, 1982). This test measures speed of information processing. It features a code that matches digits 1 to 9 with meaningless symbols. Participants are provided with rows of boxes containing the symbols in random order and a blank space below them. Participants must produce the appropriate digit for each symbol. The test involves two trials, each lasting 90 seconds, in which they must produce as many correctly matched digits as possible. In the first trial, the participants write the correct number for each symbol in the blank spaces provided and in the second they verbally produce the digits. The second trial provides a measure of speed of information processing without a hand motor component. The two different administrations of the test, using the two different response modalities, can follow each other directly because neither order of administration nor recency of first administration affects performance (Lezak, 1995). Scores can range from zero to 110. For the purposes of the study, only the scores for the written version were used. This was because no participants presented with a significant hand motor deficiency that would retard scores on the written test (the written and oral tests had a Pearson's Correlation of .92).

The *Spatial Span* subtest from the third edition of the Wechsler Memory Scale (Wechsler, 1997) was used to measure spatial memory. It involves the test administrator touching the tops of a group of ten small cubes (blue cubes on a white base) in set patterns that the participant must then replicate. The test has forward and backward subtests. In the forward subtest, the participant must exactly replicate the spatial pattern presented by the administrator, while in the backward subtest, the participant must produce the pattern in reverse order. For each subtest, the number of cubes that are touched starts at two and progresses to a maximum level of nine, with two trials given at each level. The test ends when the participant fails to produce the correct pattern on both trials at any level. The score for both subtests is the number of trials for which the participant correctly reproduces the appropriate pattern, giving minimum and maximum scores of zero and 16, respectively. For the purposes of this study, only the Total Spatial Span (the sum of the two subtests) was used as the Spatial Span measure.

The *Computerised Visual Attention Test (CVAT)* was developed specifically for this study and is described in Chapter 5. The CVAT requires participants to detect and react to targets in both central and peripheral vision, and was designed to measure selective and divided attention. The measure and the method of administration are described in detail in the method section of the second pilot study (section 5.2.2). The only change to the measure was that the subtests that used a slow rate of presentation of the letters in the primary task (X-detection) were omitted. Thus, there were five subtests, which were as follows:

- primary task (X-detection) only: measure of simple attention in central vision
- secondary task (car detection) only without visual distracters (houses): measure of simple attention in peripheral vision
- secondary task only with visual distracters: measure of selective attention in peripheral vision
- dual task (primary and secondary tasks) without visual distracters on the secondary task: measure of divided attention, central and peripheral vision
- dual task with visual distracters on the secondary task: measure of divided and selective attention, central and peripheral vision

For each of these subtests, the CVAT produced measures of target detection failures, false alarms (responses in the absence of a target), and reaction time. However, as explained previously (refer to section 5.2.4), only detection failures and reaction time measures were used for this study, thus providing one measure each of accuracy and speed on the attention tasks. Detection failures are hereafter referred to as "detection errors".

The order of the CVAT subtests was varied across participants so that the relationship between the attention variables and other measures could not be confounded with learning or fatigue effects. This variation in the order of the five CVAT subtests was done according to Orthogonal Latin Squares tables printed in Fisher and Yates (1957) so that, across the entire sample, each subtest was performed first, second, third, fourth and fifth by an equal number of participants.

The functional measures used in the self-regulation study are summarised in Table 6.2. For each measure, the functional ability it assesses and the range of possible scores are provided.

Table 6.2
Health and functional measures used in the self-regulation study

Measure	Functional ability	Range of scores
Health		
General health (in DMQ)		min of zero
Medication use (in DMQ)		min of zero
Use of medications potentially hazardous for driving (in DMQ)		min of zero
Psychological functioning		
Geriatric Depression Scale	Depressed mood	0 - 30
State-Trait Anxiety Inventory	Anxiety	
State Anxiety		20-80
Trait Anxiety		20-80
Vision		
Snellen visual acuity	Visual acuity	
Left eye		6/60 - 6/5
Right eye		6/60 - 6/5
Binocular		6/60 - 6/5
Pelli-Robson contrast sensitivity	Contrast sensitivity	
Left eye		0.00 - 2.25
Right eye		0.00 - 2.25
Binocular		0.00 - 2.25
Visual field	Horizontal visual field	
Left side		0 - 90°
Right side		0 - 90°
Total		0 - 180°
Physical functioning		
Neck mobility	Neck mobility	
Left side		0 - 90°
Right side		0 - 90°
Total		0 - 180°
Mental status		
Mini Mental State Exam (MMSE)	Mental status	0 - 30
Modified Mini-Mental (3MS)	Mental status	0 - 100
Speed of information processing		
Symbol Digit Modalities Test	Speed of information processing	0 - 110
Spatial memory		
Total Spatial Span	Spatial memory	0 - 32

Table 6.2 cont.

Health and functional measures used in the self-regulation study

Visual attention		
CVAT reaction time		
Primary task	simple attention, central vision	max 1999 ms
Secondary task, no distract	simple attention, peripheral vision	max 1999 ms
Secondary task, distract	selective attention, peripheral vision	max 1999 ms
Dual task, no distract[1]	divided attention	max 1999 ms
Dual task, distract[1]	divided and selective attention	max 1999 ms
CVAT target detection		
Primary task	simple attention, central vision	0 - 100%
Secondary task, no distract	simple attention, peripheral vision	0 - 100%
Secondary task, distract	selective attention, peripheral vision	0 - 100%
Dual task, no distract[1]	divided attention	0 - 100%
Dual task, distract[1]	divided and selective attention	0 - 100%

Note. DMQ = Driver Mobility Questionnaire; CVAT = Computerised Visual Attention Test, distract = visual distracters, min of zero = minimum score of zero; max 1999 ms = maximum score of 1999 milliseconds

[1] Scores for both primary and secondary tasks were calculated for dual task subtests

6.2.2.3 On-Road Driving Assessment

Participants' driving ability was determined using an on-road driving assessment conducted by the Driver Assessment Rehabilitation Service (DARS), located in the School of Occupational Therapy at the University of South Australia. DARS is an organisation that undertakes fitness-to-drive assessments on a referral basis. Their clients are referred mostly by general practitioners, and are predominantly older drivers affected by various medical conditions, such as dementia and stroke. DARS also assesses drivers recovering from traumatic injuries, including traumatic brain injury, and older drivers who refer themselves to check on their driving ability. DARS assessments include a standardised on-road driving test conducted by an occupational therapist with postgraduate training in driver assessment and rehabilitation, and a professional driving instructor. The driving instructor directs the driver through the test route and uses dual controls to maintain safety, while the occupational therapist sits in the back seat and scores the driver on his or her performance using a standard scoring protocol.

DARS devised a set test route specifically for the study that closely matched the task requirements of a route utilised in a previous study on driving and dementia (Clark et al., 2000), which in turn had been based on testing procedures used in other studies (Dobbs, 1997; Hunt et al., 1997; Parasuraman & Nestor, 1991). The test was broken into four different sections: familiarisation, low demand, moderate demand, and high demand. The *familiarisation* section involved familiarising the driver with the controls of the vehicle, and assessing whether the driver could follow simple instructions and perform basic vehicle control tasks (e.g. starting a car and moving off). The *low demand* section was conducted on low traffic roads and mainly involved negotiating roundabouts. The *moderate demand* section involved driving on main roads but did not require complex manoeuvres. In this section, all intersections were negotiated by driving straight through or turning with a dedicated turning arrow. In the *high demand* section, drivers had to perform unprotected right turns at intersections on main roads, as well as merging manoeuvres on multi-lane roads and driving in areas featuring high pedestrian activity. The driving test, therefore, progressed through a series of increasingly challenging stages, with progressively more difficult manoeuvres required in the presence of increasingly complex traffic conditions. The on-road assessments took between 40 minutes and an hour to complete. The complete driving assessment protocol is provided in Appendix 6C.

All driving assessments were conducted in dual-controlled, medium-sized sedans (1997 Toyota Corollas) fitted with power steering and manual or automatic transmission, depending on the participant's preference. Attempts were made to maintain consistency in the personnel conducting the driving assessments but there was some variation. Two different occupational therapists were employed for the study, one conducting 57% of the assessments, with the remaining 43% conducted by the other therapist. The same driving instructor was available for 95% of the assessments.

Assessments were conducted at three different times during the day: 9:30am, 11:00am, and 1:00pm. The choice of these times meant that drivers did not have to perform any part of their driving test during peak hour traffic.

The scoring system for the on-road driving assessment was the same as that developed for a study by Clark et al. (2000). In this system, points were awarded for various component skills and behaviours for each driving manoeuvre required in the test. For some behaviours (observation, coming to a stop, mirror checks), the occupational therapist recorded whether the behaviour was exhibited or not. If recorded as “yes”, the driver was awarded one point, if recorded as “no”, no point was awarded. For some skills (speed, positioning, speed of approach, gap selection), the performance was recorded as “safe” or “unsafe”. For safe performance, one point was awarded; for unsafe performance no point was awarded. Performance of some skills (response to lights, speed at a school zone, choice of lane, selection of a location to park, selection of a location to perform a U-turn) was recorded as being either “correct” or “incorrect”. Correct performance received one point, while incorrect performance did not. In total, the low demand section was scored out of 151 points, the moderate demand section out of 106 points, and the high demand section out of 161 points, giving a total maximum score of 418 points. The familiarisation section was not scored. A complete description of the scoring criteria is provided in Appendix 6D.

Although the scoring protocol was detailed, there was no cut-off score indicating that a driver had passed or failed the test. As is standard practice for DARS, test failure was based on agreement between the occupational therapist and driving instructor about the safety risk posed by the driver, given the types of errors that they made and the level of active intervention required on the part of the driving instructor to ensure safety during the test (applying brakes, taking hold of the steering wheel, explicit verbal guidance to aid execution of manoeuvres). Errors that posed a greater safety risk, such as speeding, disregarding traffic signals and Stop or Give Way signs, drifting into other lanes, and stopping unexpectedly without reason, were most likely to be associated with failure of the test.

In order to take into account the differential emphasis placed on different error types in determining the overall outcomes of the driving assessments, raw scores for the driving test (out of 418) were not used as an outcome measure for the study. In keeping with the studies by Dobbs et al. (1998), Janke and Eberhard (1998) and Staplin et al. (1998b), in which different weightings were given for different road test errors, a weighted scoring system was developed that assigned different weightings to different errors in order to produce an overall score that more closely matched the outcomes of the assessments (i.e. pass or fail). Errors were classified as either “habitual” (mistakes probably made habitually that are unlikely to place the driver in danger of a crash) or “hazardous” (mistakes with a greater potential for leading to crash involvement). Habitual mistakes included failure to check mirrors or blind spots, failure to indicate, inappropriate lane selection and poor parking ability. Hazardous errors included exceeding the speed limit, inappropriate high speed, unsafe gap selection, unsafe positioning, and disobeying traffic lights. Disobeying a Stop sign was classed as hazardous if the participant drove through the junction in a manner indicative of not noticing the sign, while merely creeping over the Stop line without having come to a complete stop was classed as an habitual error. If the driving instructor felt it necessary for safety reasons to actively intervene (applying brakes, taking hold of the steering wheel, explicit guidance to aid the execution of manoeuvres), then this was recorded as a “driving instructor intervention”. It was decided that the overall score for the driving test would combine these different error types but with weightings determined on the basis of best matching the scores to the pass/fail judgements made by the assessors.

The sensitivity (correctly identified failures), specificity (correctly identifying passes) and diagnostic power (overall percentage correct) were calculated for a number of different combinations of weightings for driving instructor interventions, hazardous errors and habitual errors. For each combination of weighted errors, a cut-off score was chosen to maximise diagnostic power but, in keeping with the suggestion of Janke and Eberhard (1998), it was also decided to try and maximise sensitivity while maintaining very high levels of specificity. Table 6.3 provides a number of equations using weightings of the different error types, and the levels of sensitivity, specificity and diagnostic power associated with the cut-off scores (a score equal to the cut-off was classified as a likely pass). It shows that the best diagnostic power (94%) was achieved with a score using 10 times the driving instructor interventions, plus five times the hazardous errors, plus the habitual errors, and a cut-off score of 199. The sensitivity for this equation and cut-off score was 79% and the specificity was 97%.

Table 6.3
Combinations of error types, cut-off scores, sensitivity, specificity, and diagnostic power for the on-road assessment (N=90)

Equation	Weightings for different error types			Cut-off	Sensitivity	Specificity	Diagnostic Power
	DII	Hazardous	Habitual				
1	1	0	0	2	71	95	91
2	1	0	0	1	93	86	87
3	0	1	0	19	79	95	92
4	2	1	0	20	86	88	88
5	6	3	1	139	79	95	92
6	8	4	1	170	79	95	92
7	10	5	1	199	79	97	94
8	5	5	1	180	79	93	91
9	5	10	1	281	79	92	90

Note. DII = Driving Instructor Interventions

In the studies by Staplin et al. (1998b) and Janke and Eberhard (1998), the weighted error score used was based on three times the number of "critical" errors plus five times the number of "hazardous" errors plus other errors. In these studies, critical errors were errors that would normally lead automatically to test failure, while hazardous errors were a subset of critical errors that were dangerous enough to require intervention from the examiner. These "critical" and "hazardous" errors seem to correspond with the present study's hazardous errors and driving instructor interventions, respectively. This suggests that the present study is consistent with those of Staplin et al. (1998b) and Janke and Eberhard (1998) in terms of the relative weightings of different errors used to determine driving performance scores.

A recent study by DiStefano and MacDonald (2003) looked at the types of errors most predictive of driving test failure among older drivers referred for a licence assessment. They found that driving instructor interventions were most closely associated with the outcome, and that these interventions were most often made during intersection negotiation, to maintain position and speed and to ensure an adequate safety margin during gap selection. The scoring model they developed provided diagnostic power of 94%. Again, these findings fit well with the model developed for the present study, which also emphasised driving instructor interventions and produced a level of diagnostic power of 94%.

6.2.3 Procedure

The recruitment of participants from the general community occurred at information sessions at Senior Citizens and Australian Retired Persons Association clubs, at which the names and telephone numbers of interested people were collected. These people were later contacted by telephone and given more detailed information about the study, allowing an informed choice concerning participation. DARS clients, on the other hand, were told about the study by the DARS administrative officer and the names and telephone numbers of those interested in the study were passed on to the Investigator, who then contacted the clients to provide them with more detailed information about the study and asked them if they wanted to participate.

Participants recruited from the general community completed the various components of the study in a set order. First, they completed the Driver Mobility Questionnaire, which was mailed out to them. Next, they attended an individual session at the University of Adelaide in which they completed the functional tests (i.e. the visual, physical, psychological and neuropsychological tests). Within two weeks following the testing session, they had their driving assessment with DARS. The participants recruited from the pool of DARS referrals also completed the questionnaire prior to the functional test session but the test session could occur within two weeks prior to, or following, their on-road assessment.

Prior to the functional test session, participants were sent a copy of the Driver Mobility Questionnaire, an appointment sheet for their testing session, an information sheet about the study (the general community participants' information sheet is provided in Appendix 6E and the referral participants' information sheet is provided in Appendix 6F), a map showing the location of the testing session at the University of Adelaide, and a taxi voucher to enable travel to and from the University. When the participants arrived for the functional testing session, they gave written informed consent for each component of the study. Both groups (general community and referral) filled in consent forms for the questionnaires and functional tests (same form as for the pilot study - provided in Appendix 5B), and for provision of their driver's licence numbers to allow the checking of official crash records (form provided in Appendix 6G). Participants from the general community also filled in a consent form for undertaking a driving assessment (provided in Appendix 6H) and the referral group filled in a consent form to allow the Investigator to obtain a copy of the results of their driving assessments from DARS (provided in Appendix 6I). Separate consent forms were used so that participants could decide not to participate in certain parts of the study (on-road test, provision of licence number) if they wished. A driver's licence number was not provided by 4.8% of the sample, while 11.8% of the general community group decided not to perform the on-road test. After completing the consent forms, participants were asked if they had had any problems with the questionnaire and, if so, the investigator discussed these problems, and ensured that the participants understood the questions and had answered all items.

The functional tests were also administered in a set order. After recording the participant's age, sex, years of education, and driver's licence number (for those who consented), the testing session began with the participant completing pen and paper versions of the Geriatric Depression Scale and State Trait Anxiety Inventory. Next, the Modified Mini Mental State Examination was administered. Vision was tested next, using the Snellen Static Visual Acuity chart, the Pelli-Robson Contrast Sensitivity Test, and the simple test of visual field.

Next, the Computerised Visual Attention Test (CVAT) was explained and demonstrated to the participant, who was given practice on each component of the test. After completing all of the practice trials, the participant completed the first subtest. The remaining non-computer administered functional tests were interpolated between the CVAT subtests to ensure that participants did not have to spend more than five consecutive minutes looking at the computer screen.

After the first CVAT subtest[3], participants completed the Wechsler Test of Adult Reading. This was followed by the second CVAT subtest, which was, in turn, followed by the Digit Symbol Modalities Test, with the written version first and the oral version second. The third CVAT subtest was next, followed by measurement of neck mobility with a goniometer. After the measurement of neck mobility, participants performed the fourth CVAT subtest. Finally, the participant undertook the Spatial Span Test and finished with the fifth CVAT subtest.

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[3] *NB*: The order of presentation of the CVAT subtests varied between participants (refer to section 6.2.2.2).

All functional test sessions were conducted by the same researcher and in the same office at the Centre for Automotive Safety Research, the University of Adelaide. The sessions were conducted on week days and began at either 10am or 2pm. The sessions usually took approximately two hours. Participants were informed before they began that, at the end of any test, they were permitted to take a break before starting the next test.

At the conclusion of the functional testing session, all materials required for the driving assessment by participants recruited from the general community were provided (i.e. another appointment sheet, another map showing the location of DARS in the University of South Australia, and taxi vouchers for travel to and from the driving assessment). For the referral group, all arrangements regarding the driving assessment were left solely to DARS.

All participants were paid $25 for completing the questionnaires and the functional testing session. Participants recruited from the general community were paid an additional $25 for undertaking a driving assessment. Participants referred to DARS for an assessment were not paid for their driving test as they were obliged to have a test, regardless of the study. The cost of the driving assessment for participants from the general community ($165) was paid using study funds, but those referred for an assessment had to meet the cost themselves.

For the general community participants, feedback on the driving assessment was given by the occupational therapist immediately following the test. Drivers recruited from the general community who failed the on-road test did not have their licence cancelled. Instead, a letter was sent to their general practitioner who would decide what, if any, action was required. For both groups of participants, general feedback regarding performance on the functional tests was given over the telephone by the investigator.

6.3 Study Two: Validation of the Computerised Visual Attention Test

6.3.1 Participants

A subset of 20 participants (6 males, 14 females) from the larger study on older driver self-regulation was recruited for the validation study. These 20 participants were all from the general community and recruited through Senior Citizens Clubs and Australian Retired Persons Association clubs in metropolitan Adelaide. They ranged in age from 60 to 85, with a mean of 73.8 ($SD = 6.5$). The number of years of formal education for the sample ranged from seven to 21, with a mean of 11.0 ($SD = 3.3$). Their IQs, estimated from scores on the Wechsler Test of Adult Reading (Wechsler, 2001), ranged from 87 to 125, with a mean of 109.2 ($SD = 11.7$).[4]

6.3.2 Materials

In addition to the CVAT developed for the self-regulation study, the participants also completed the state anxiety section of the State-Trait Anxiety Inventory (refer to section 6.2.2.2) for a second time. This was done to ensure that test-retest reliability was not affected by differences in state anxiety between the two testing sessions. Participants also completed four other tests that are purported to measure attention. These were as follows:

Paced Auditory Serial-Addition Task (Gronwall, 1977). This test assesses rate of information processing, and sustained and divided attention. A pre-recorded tape delivers a series of 61 single digit numbers (1 to 9). The participant must add each number to the one preceding it on the tape, so that the second number is added to the first, the third is added to the second, and so on. Responses are verbal. There are four different lists presented at four different rates of presentation: a number every 2.4s, 2.0s, 1.6s and 1.2s. The order of the lists is always the same, progressing from the slowest to

[4] Independent samples *t* tests were used to assess whether the sub-sample of participants involved in the validation study were different from the participants who were not. There were no differences between the two groups in terms of age, years of education or estimated IQ.

the fastest rate of presentation. The scores for each list are the number of correct additions out of a total of 60. For the purposes of minimising the number of scores to be analysed in the study, the four PASAT scores were averaged to produce an overall score for the test. The PASAT takes approximately 15 minutes to administer.

Ruff 2 and 7 Selective Attention Test (Ruff, Evans, & Light, 1986; Ruff, Niemann, & Allen, 1992). This is a paper and pencil measure of selective attention in which participants must cross out "2"s and "7"s (targets) embedded randomly in rows of either letters of the alphabet or other digits (distracters). The stimuli are arranged in 20 blocks of three rows, with 50 stimuli (targets and distracters) in each row. Participants are allowed 15s for each block, giving a total time of five minutes to complete the test. Scores for each block are the number of hits (correctly crossed out targets), and the number of omissions (missed targets) and commissions (incorrectly crossed out distracters). Scores are summed separately for the 10 blocks featuring letters as distracters and the 10 blocks featuring digits as distracters. For the purposes of the study, overall scores for the two conditions (letters or numbers as distracters) were calculated by subtracting the number of omissions and commissions from the number of hits. A similar test to this has been found previously to be related to the crash involvement (Marottoli et al., 1998) and driving performance (Richardson & Marottoli, 2003) of older drivers.

Delis-Kaplan Executive Functioning System Colour-Word Interference Test (Delis, Kaplan, & Kramer, 2001). This is a measure of selective attention and cognitive flexibility based on a test that was first developed by Stroop (1935). For the present study, only conditions 3 and 4 were administered. In condition 3 (inhibition) participants must name the colour of the ink that a series of words are printed in, with the words being the names of colours that conflict with the ink colour. For example, the word "blue" written in green ink requires the answer, "green". This condition, therefore, requires the participant to inhibit the tendency to read the word. In condition 4 (switching), half of the words have boxes drawn around them and, for these words, participants must read the word itself, ignoring the ink colour. For the words without boxes, participants must respond with the ink colour, as in condition 3. This condition, therefore, requires the participant to switch between response categories. Both conditions have a time limit of 180s. Raw scores are the time taken to give all 50 answers, the number of uncorrected errors, and the number of self-corrected errors for each condition. For this study, only the time taken in each condition was used in the analyses. The test takes approximately ten minutes to administer. Variations of this test have previously been found to be related to crash involvement (Daigneault et al., 2002a) and driving performance (Clark et al., 2000) among older drivers.

Delis-Kaplan Executive Functioning System Trail Making Test (Delis et al., 2001). This test, based on a test first developed by Partington (1949), combines selective attention, sequencing, mental flexibility, visual search, and motor function. The Delis-Kaplan version includes five conditions, three of which (conditions 2, 3 and 4) were used in this study. All conditions involve encircled numbers and/or letters randomly arranged on a large piece of paper. In condition 2, participants must draw pencil lines connecting 16 numbers in ascending order. In condition 3, they must connect 16 letters in alphabetical order, while in condition 4, they must alternate between ascending numbers and alphabetically ordered letters. That is, they must connect 1 to A to 2 to B, and so on, until finishing with connection of 16 to P. When an error is made in any subtest, the examiner points out the error and asks the participant to correct it before proceeding. For conditions 2 and 3, a maximum time of 150s is given to complete the test, while for condition 4, the time limit is 240s. Scores for each subtest of the Trail Making Test are the number of errors made, and time taken for completion. In this study, only the raw scores for test completion time were used in all analyses. The test takes approximately ten minutes to administer. Performance on variations of this test have previously been found to be related to crash involvement (Lundberg et al., 1998; Stutts et al., 1998) and driving performance (Clark et al., 2000; Cushman, 1996; Janke, 2001) among older drivers.

6.3.3 Procedure

After participants completed the laboratory testing session for the self-regulation study, they were provided with an information sheet concerning the CVAT validation study (provided in Appendix 6J). After participants had completed the driving test, they were contacted by telephone and asked if they were willing to be involved in the validation study. Those who were willing received an appointment sheet, map of the University, and taxi vouchers in the mail. The second testing session was organised so that it was one month after the first test session for each participant. Recruitment continued until a sample of 20 participants had agreed to take part in the validation study.

Upon arrival for the validation study testing session, participants were required to fill in a form giving their informed consent for participation (provided in Appendix 6K). Next, they were asked to complete the state anxiety section of the State-Trait Anxiety Inventory. This was followed by the first of the five CVAT subsets. The test was explained and practice given in exactly the same manner as when the participants undertook the test in the testing session for the self-regulation study. Also, the order of the different subtests for each participant was the same as in the previous session.

Following the first subtest of the CVAT, participants performed the remaining tests in the following order: Paced Auditory Serial Addition Task, second subtest of the CVAT, Ruff 2 and 7 Selective Attention Test, third subtest of the CVAT, D-KEFS Colour-Word Interference Test, fourth subtest of the CVAT, Trail Making Test, fifth subtest of the CVAT.

Consistent with the self-regulation study, all test sessions were conducted by the same researcher and in the same office at the Centre for Automotive Safety Research, at the University of Adelaide. The sessions were conducted on week days and began at either 10am or 2pm. The sessions took approximately ninety minutes. Participants were informed before testing began that, at the end of any test, they were permitted to take a break before starting the next test. At the end of the session, participants were given a taxi voucher for travel home and $25 for completion of the testing. They were contacted later by telephone and given general feedback concerning their performance.

CHAPTER 7: VALIDATION STUDY FOR THE COMPUTERISED VISUAL ATTENTION TEST

7.1 Introduction

In order to examine the relationship between functional abilities and the self-regulatory practices of older drivers, a test was developed to measure visual attention: the Computerised Visual Attention Test (CVAT). As part of the process of developing and using a new test, it is necessary to assess the test's reliability and validity. To this end, a study was conducted in which participants completed the CVAT for a second time, enabling an assessment of test-retest reliability. Participants also completed a number of standard tests of attention and, by examining the relationships between the newly developed CVAT and the established measures of attention, it was possible to assess the construct validity of the CVAT. Finally, the predictive validity of the CVAT was assessed by examining its relationship with on-road driving ability. Details of the methods used for this study were provided in section 6.3.

7.2 Statistical Analyses

Test-retest reliability was assessed by calculating Pearson's Product Moment Correlation coefficients between test scores in the first and second test sessions. Construct validity was evaluated by calculating Pearson's correlations between scores on the CVAT and the established tests purported to measure attention. Finally, predictive validity was assessed by examining correlations between the weighted error score on the driving test (see section 6.2.2.3) and both the CVAT and the established attention tests. For all tests, statistical significance was accorded any test result with $p<.05$. With a sample of 20 participants, only correlations of .45 or greater reach statistical significance. This meant that only high-moderate to strong correlations (Cohen, 1992) were identified as significant. All statistical analyses were conducted using SPSS 10 for Macintosh software.

7.3 Results

7.3.1 Descriptive Statistics

State anxiety was measured in the validation testing session using the State-Trait Anxiety Inventory (Speilberger, 1983), described in section 6.2.2.2. The means were 29.8 (*SD* = 8.6) for the first session (self-regulation study test session) and 30.9 (*SD* = 10.5) for the second (validation study test session). These means were not found to differ significantly ($t_{(19)} = -.72$, $p = .483$), indicating that there were no differences in state anxiety that could affect results on the two separate administrations of the CVAT. Table 7.1 shows the descriptive statistics for the standard attention tests, which were only administered once. The mean score for the PASAT was slightly below those of the oldest age group (50 to 69) in the published norms of Stuss, Stethem and Pelchat (Stuss, Stethem, & Pelchat), which is likely to be due to an older participant age range in this study. Similarly, mean scores for the Ruff 2s and 7s Selective Attention Test were slightly below average compared to the norms for those aged 55 to 70 (Ruff et al., 1986). All scores for the Colour Word Interference Test and the Trail Making Test were slightly above average for adults aged between 60 and 79, except for Trails Switching, which was in the average range (Delis et al., 2001).

Table 7.2 shows statistics for reaction time scores on the visual attention test for the two separate testing sessions. The pattern of means and standard deviations for CVAT reaction time scores were similar across the two sessions, although reaction times tended to be slightly shorter in the second session.

Table 7.1
Means and standard deviations for standard attention tests

Test measure	Mean	Standard deviation
PASAT	30.0	9.1
Ruff 2 and 7s Selective Attention Test		
Digit-Digit	103.9	20.8
Digit-Letter	100.0	25.6
Colour-Word Interference Test		
Inhibition, time	67.3	14.5
Switching time	69.5	16.1
Trail Making Test		
Numbers, time	43.7	14.9
Letters, time	48.5	19.3
Switching, time	118.8	48.1

Note. PASAT = Paced Auditory Serial Addition Test

Table 7.2
Descriptive statistics for median reaction times on the CVAT in the two testing sessions

CVAT tasks	First session		Second session	
	Mean (ms)	*SD*	Mean (ms)	*SD*
Single task				
Primary	433.8	38.5	434.8	36.4
Secondary, no visual distracters	430.5	52.9	424.8	50.1
Secondary, visual distracters	558.3	76.8	544.3	93.4
Dual Task				
Primary, no visual distracters on secondary	476.5	41.4	462.8	39.2
Secondary, no visual distracters	484.0	67.0	473.0	64.5
Primary, visual distracters on secondary	490.5	31.7	477.5	39.3
Secondary, visual distracters	627.8	112.0	591.5	100.7

Note. CVAT = Computerised Visual Attention Test

Table 7.3 shows statistics for target detection performance for the two separate sessions. The detection error percentages demonstrate a noticeable reduction in the second testing session compared to the first.

As indicated in section 6.2.2.3, performance on the driving test was measures using a weighted error score based on the following equation:

10 (driving instructor interventions) + 5 (hazardous errors) + habitutal errors

For the 20 participants in the CVAT validation study, the mean score on the driving test was 129.5 (*SD* = 57.8). Performance on the driving test was used as an outcome measure for assessment of the CVAT's predictive validity.

Table 7.3
Descriptive statistics for detection errors on the CVAT in the two testing sessions

CVAT tasks	First session		Second session	
	Mean	*SD*	Mean	*SD*
Single task				
Primary	0.5	1.2	0.0	0.0
Secondary, no visual distracters	0.2	0.8	0.2	0.8
Secondary, visual distracters	2.1	4.2	0.6	1.4
Dual Task				
Primary, no visual distracters on secondary	3.1	4.8	0.8	1.3
Secondary, no visual distracters	0.9	2.7	0.6	1.8
Primary, visual distracters on secondary	6.4	7.3	3.7	5.6
Secondary, visual distracters	7.4	11.8	2.9	4.6

Note. CVAT = Computerised Visual Attention Test

7.3.2 Test-Retest Reliability

In order to assess the test-retest reliability of the CVAT, Pearson's product-moment correlations were calculated between scores on the CVAT in the first and second testing sessions. The test-retest correlations for the median reaction time scores and detection errors are shown in Table 7.4. It can be seen that five of the seven test-retest correlations for the reaction time measures of the CVAT were .80 or more, indicating good reliability. The only measure with a reliability of less than 0.7 was reaction time on the secondary task in the single task condition, without visual distracters, which had a test-retest correlation of .63.

Table 7.4

Test-retest correlations for median reaction times and detection errors on the CVAT

CVAT tasks	Median reaction time	Target detection error
Single task		
Primary	.82**	-
Secondary, no visual distracters	.63**	-.05
Secondary, visual distracters	.81**	-.09
Dual Task		
Primary, no visual distracters on secondary	.74**	.58**
Secondary, no visual distracters	.80**	.79**
Primary, visual distracters on secondary	.80**	.80**
Secondary, visual distracters	.82**	.60**

Note. CVAT = Computerised Visual Attention Test
* $p < .05$, ** $p < .01$

Few of the detection error percentages had test-retest correlations as strong as those for the median reaction time scores. Detection errors on the primary task in the dual task condition featuring visual distracters and on the secondary task in the dual task condition without visual distracters were the only measures with test-retest correlations of approximately .80. Correlations for the secondary task in the single task conditions were very low and no participants failed to detect an X (primary task) in the single task condition in the second test session, making the calculation of a correlation impossible.

7.3.3 Construct Validity

Pearson's product-moment correlations between the CVAT and the standard tests of attention were calculated in order to assess the construct validity of the CVAT. This was done for all of the CVAT median reaction time scores and the target detection error scores from the dual task CVAT subtests, using scores from the first test session. The detection error scores from the single task subtests were not used due to low reliability.

An inter-correlation matrix for the reaction time scores and standard attention tests is provided in Table 7.5. There were only two significant correlations with the established tests of attention. Secondary task reaction times in the dual task condition with visual distracters was correlated with the Ruff 2 and 7s Selective Attention scores for both detection of targets among the letters and among the digits. The negative correlation means that poorer performance on the CVAT (longer reaction time) was associated with poorer performance on the Ruff test (fewer targets detected).

There were more significant correlations between established tests of attention and the detection errors on the CVAT (see Table 7.6 for a complete inter-correlation matrix). There were four significant correlations with detection errors on the primary task in the dual task condition without visual distracters on the secondary task. These were with the Ruff test for detection of targets, both among the letters and among the digits; time on the Trails switching task; and time on the Colour Word inhibition task. There were two significant correlations with detection errors for the primary task in the dual task condition with visual distracters on the secondary task. These were with the Ruff test for detection of targets among the letters, and among the digits.

Table 7.5
Inter-correlation matrix for the CVAT reaction time scores and standard tests of attention

	CVAT reaction times						
Attention Tests	Prim only	Sec only, no distract	Sec only, distract	Prim, dual, no distract	Sec, dual, no distract	Prim, dual, distract	Sec, dual, distract
PASAT	-.02	.25	-.04	.21	.10	.03	-.10
Ruff D-D	-.08	-.20	-.43	-.36	-.22	-.40	-.55*
Ruff D-L	-.03	-.03	-.30	-.10	-.25	-.32	-.65*
CW Inhib	.20	.21	.33	.27	.17	.28	.34
CW Swit	.02	.11	.19	.27	.10	.11	.25
Trails Num	-.24	-.09	-.06	-.12	-.04	-.08	.11
Trails Let	.13	.25	.02	.11	-.06	-.03	.01
Trails Swit	-.22	-.15	-.12	.10	-.23	-.01	.05

Note. CVAT = Computerised Visual Attention Test; Prim = primary task; Sec = Secondary task; distract = visual distracters; dual = dual task; PASAT = Paced Auditory Serial Addition Test; Ruff D-D = Ruff 2s and 7s Selective Attention Test, digits condition; Ruff D-L = Ruff 2s and 7s Selective Attention Test, letters condition; CW Inhib = Colour Word Interference Test, inhibition condition; CW Swit = Colour Word Interference Test, switching condition; Trials Num = Trail Making Test, Number Sequencing; Trails Let = Trail Making Test, Letter Sequencing; Trails Swit = Trail Making Test, Switching condition
* $p < .05$

Table 7.6
Inter-correlation matrix for the CVAT detection error scores and standard tests of attention

	CVAT detection errors			
Attention Tests	Prim, dual, no distract	Sec, dual, no distract	Prim, dual, distract	Sec, dual, distract
PASAT	-.42	.38	-.30	-.04
Ruff D-D	-.50*	-.16	-.46*	-.34
Ruff D-L	-.52*	-.09	-.48*	-.36
CW Inhib	.46*	.19	.25	.36
CW Swit	.35	.15	.25	.19
Trails Num	.12	-.03	.05	.04
Trails Let	-.02	-.12	-.22	.09
Trails Swit	.56*	-.19	.39	.00

Note. CVAT = Computerised Visual Attention Test; Prim = primary task; Sec = Secondary task; distract = visual distracters; dual = dual task; PASAT = Paced Auditory Serial Addition Test; Ruff D-D = Ruff 2s and 7s Selective Attention Test, digits condition; Ruff D-L = Ruff 2s and 7s Selective Attention Test, letters condition; CW Inhib = Colour Word Interference Test, inhibition condition; CW Swit = Colour Word Interference Test, switching condition; Trials Num = Trail Making Test, Number Sequencing; Trails Let = Trail Making Test, Letter Sequencing; Trails Swit = Trail Making Test, Switching condition
* $p < .05$

7.3.4 Predictive Validity

If the CVAT is to be useful in studies of older drivers, then it needs to be a better predictor of driving ability than other existing measures of attention (to have better “predictive validity” for measures of driving performance). To assess this, Pearson’s product-moment correlations were calculated between all of the attention measures, including the CVAT, and the weighted error score on the driving test. These correlations are shown in Tables 7.7 (for CVAT measures) and 7.8 (for the standard attention tests). Correlations were not calculated for target detection in the single task CVAT subtests because of low reliability.

Among the reaction time scores, significant correlations with driving performance were found for the secondary task in the single task condition with visual distracters, the secondary task in the dual task condition without visual distracters, and the secondary task in the dual task conditions with visual distracters. Among the detection error scores, a significant correlation with driving performance was found for the secondary task in the dual task condition with visual distracters. For the established tests of attention, there was only one significant correlation with driving performance, that for Trail Making, Number Sequencing. These results suggest better predictive validity, with regard to driving performance, for the CVAT than for the established tests of attention.

Table 7.7
Correlations between driving performance and median reaction times and detection errors on the CVAT

CVAT tasks	Correlation with driving performance	
	Median reaction time	Target detection error
Single task		
Primary	.32	
Secondary, no visual distracters	.39	
Secondary, visual distracters	.52*	
Dual Task		
Primary, no visual distracters on secondary	.14	.41
Secondary, no visual distracters	.64**	.32
Primary, visual distracters on secondary	.24	.09
Secondary, visual distracters	.51*	.50*

Note. CVAT = Computerised Visual Attention Test
* $p < .05$, ** $p < .01$

Table 7.8
Correlations between driving performance and standard attention tests

Test measure	Correlation with driving performance
PASAT	-.18
Ruff 2 and 7s Selective Attention Test	
Digit-Digit	-.23
Digit-Letter	-.24
Colour-Word Interference Test	
Inhibition, time	.30
Switching time	.34
Trail Making Test	
Numbers, time	.46*
Letters, time	.13
Switching, time	.15

Note. PASAT = Paced Auditory Serial Addition Test
* $p < .05$

7.4 Discussion

In order to assess the test-retest reliability of the Computerised Visual Attention Test (CVAT), a small sample of older adults were asked to complete the test a second time, one month after they first completed it. The test-retest correlations for the CVAT were generally better for the reaction time scores (around .80) than for the detection error scores. Two of the latter measures had test-retest correlations of approximately .80, two had correlations of approximately .60 and the remaining three (all single task conditions) were not significantly different from zero.

These lower test-retest correlations for the detection scores could be due to a high number of participants detecting 100% of the targets. For secondary task target detection in the single task condition without visual distracters, all of the cars were detected by 19 out of 20 participants in both sessions. For secondary task target detection in the single task condition featuring visual distracters, 14 out of 20 participants detected all the targets in the first session and 17 out of 20 detected them all in the second session. The detection of all targets by the majority of participants led to restricted ranges of scores for these variables, which, in turn, may have affected the correlational analyses. The target detection score with the highest test-retest correlation was for the primary task in the dual task condition featuring distracters on the secondary task, a task for which all of the targets were detected by only four participants in the first session and two participants in the second session.

Improved target detection in the second session is likely to be due, in part, to practice effects. Practice effects were also apparent for the reaction time tasks but were not as large as those for the detection error scores. Importantly, the pattern of means for the reaction time scores stayed the same over the two sessions. That is, in both test sessions, reaction times increased in the dual task conditions (divided attention effect) and in the presence of visual distracters (selective attention effect).

Another reason for the excellent target detection by most participants was the use of a sample of healthy, community-dwelling adults. It could be that a better indication of the test-retest reliability of the detection error scores could be obtained by repeating the study using a larger sample of older adults affected by various impairments (e.g. visual, cognitive) who would be more likely to miss a greater percentage of the targets.

In order to assess the construct validity of the CVAT, correlations between this and other accepted measures of attention were examined. It was found that detection error scores showed better correlations with the other attention measures than did reaction time scores. This may indicate that the detection of targets is more closely related to pure attentional ability than reaction time, for which speed of information processing may be a major component.

The only established test of attention with which the CVAT was well correlated was the Ruff 2 and 7s Selective Attention Test, especially for reaction times to cars embedded within visual distracters. This suggests a common requirement for selective attention. In contrast, the established test of divided attention, the PASAT, did not correlate with any of the CVAT measures.

The low number of significant relationships between the CVAT and the Trail Making Test, Colour Word Interference Test and PASAT could be due to "attention" being a multi-faceted ability. The CVAT could be measuring other aspects of attention not measured by these other attention tests. It is also likely that the CVAT and the established tests of attention are not pure measures of attention but also measures of non-attentional abilities. If there are considerable differences between the tests in terms of the non-attentional abilities they measure, then there is a limit to the extent that they are likely to share common variance. As noted, the reaction time component of the CVAT requires good speed of information processing. The PASAT would also assess mathematical ability, an ability not required by the CVAT. The two tests taken from the Dellis-Kaplan Executive Functioning System (Colour Word Interference and Trail Making) are both purported to measure selective attention but would also be expected to make large demands on executive functioning capabilities.

It also needs to be borne in mind that the reliability of a test places a limit on any correlations calculated between that test and any other measure. Thus, correlations between the CVAT and the established tests of attention have, as an upper limit, not 1.0 but the square root of their reliability (Carmines & Zeller, 1979). This means that, for the seven reaction time scores on the CVAT, the maximum correlations possible with the established tests of attention ranged between .80 and .90. For the four detection error scores in the dual task conditions (ignoring the detection error scores in the single task conditions for which the reliability coefficients were not significantly different from zero), the maximum correlations possible with other measures ranged from .76 to .89.

Upper limits on correlations caused by less than perfect reliability would also apply to the established tests of attention. For the Ruff 2s and 7s Test, with which the CVAT shared the most significant correlations, test-retest reliability coefficients have been found to range from .84 to .97 (Spreen & Strauss, 1997), giving high upper limits for correlations with other measures ranging from .92 to .98. Similarly, the PASAT has high test-retest reliability coefficients of over .9 (Spreen & Strauss, 1997). However, for the Trail Making Test, the test-retest reliability coefficients among those aged between 50 and 89 were .37 (number sequencing), .70 (letter sequencing) and .55 (switching) (Delis et al., 2001), giving low upper limits for correlations of .61, .84 and .74, respectively. Similarly, the test-retest reliability coefficients among those aged 50 to 89 for the Colour Word Interference Test were .50 for the inhibition condition and .57 for the switching condition (Delis et al., 2001), giving upper limits for correlations of only .71 and .75, respectively. These restrictions on the upper limits of correlations with other variables could also have contributed to the low number of significant correlations between the CVAT and the established tests of attention, especially for the Trail Making and Colour Word Interference tests.

Although the construct validity of the CVAT was unable to be firmly established, it was still important to assess the degree to which the test could predict driving test performance compared to the established tests of attention. It was found that three reaction time scores and one detection error score were significantly correlated with the weighted error score on the driving test. Of the eight scores from the established tests of attention, only one (Trail Making Number Sequencing) was significantly correlated with driving test performance. This suggests that the CVAT is more useful than established tests of attention for predicting driving ability.

It is important to note that this study included only a small sample of 20 participants, which meant that Pearson's correlation coefficients had to reach .45 before being statistically significant. This study was therefore only able to detect large effect sizes. However, a stringent criterion is appropriate for the assessment of reliability and validity and reliability, for which it is important to have this magnitude or greater.

The overall conclusion from the validation study is that the reaction time scores of the Computerised Visual Attention Test (CVAT) show good reliability but that a number of detection error scores (those for the single task conditions) were not shown to be reliable for healthy older adults. The construct validity has not been established, except that the task of detecting targets (cars) in the presence of visual distracters is related to selective attention, as intended. Further validation of the test in the future may require comparison to more complex, computer-administered tasks of divided attention and speed of information processing, such as the Useful Field of View test (Owsley et al., 1998), and use of samples of older adults with a broader range of abilities (e.g. visual, cognitive). The CVAT has, however, been shown to be a better predictor of driving ability than established tests of attention previously linked to driving test performance measures. The overall conclusions, therefore, are that the CVAT is a reliable measure of abilities including, but not restricted to, attention, and that the CVAT is correlated with driving ability. On the basis of these findings, the CVAT appears to be an appropriate functional measure for use in a study of older driver self-regulation.

CHAPTER 8: THE RELATIONSHIP BETWEEN HEALTH, FUNCTIONAL AND DRIVING MEASURES

8.1 Introduction

This chapter examines the relationships between health and functional measures and on-road driving performance. First, there is an examination of the relationships between these variables and age, in order to determine if increasing age was associated with poorer health, poorer functional abilities and deficits in driving ability. If poorer driving performance was found to be related to increasing age, then the relationships between driving performance and the health and functional measures would need to be shown to be independent of age. The relationships between the health and functional measures and driving performance are then examined and the measures most predictive of driving performance are identified. These findings are then compared to those of other studies that have examined these relationships.

The findings in this chapter are used in analyses presented in a later chapter (Chapter 11) comparing the health and functional measures related to driving performance with the health and functional measures related to the avoidance of difficult driving situations (self-regulation). If the two sets of measures are similar, then that would suggest that older drivers are limiting their driving in response to declines in the health factors and functional abilities that are related to driving difficulties. This, in turn, would suggest that older drivers are able to practise self-regulation in a manner that limits safety risks without unduly restricting mobility.

As discussed in section 3.2, there is a relationship between crash involvement or poorer driving ability and a number of medical conditions, including cataract (e.g. Owsley et al., 1999), glaucoma (e.g. Wood, 2002b), dementia (e.g. Cooper et al., 1993b), cerebrovascular accidents (e.g. Sims et al., 2000), diabetes mellitus (e.g.

Vernon et al., 2002), epilepsy (e.g. Hansotia & Broste, 1991) and various medications (anti-depressants, benzodiazepines, analgesics, hypnotics, antipsychotics, antihypertensives, non-steroidal anti-inflammatory drugs, anticoagulants and hypoglycaemics) (e.g. Ray, Gurwitz et al., 1992). Concerns have also been expressed about the effects of multiple medical conditions on the driving capabilities of older drivers (e.g. Marottoli, 2002).

Various functional measures have also been related to on-road driving ability or crash involvement. These have included visual acuity (e.g. Vernon et al., 2002), contrast sensitivity (e.g. Wood, 2002a), visual field (e.g. Johnson & Keltner, 1983), head and neck flexibility (e.g. Marottoli et al., 1998), mental status (e.g. Clark et al., 2000), speed of information processing (e.g. Janke, 2001), spatial memory (e.g. Lundberg et al., 1998), and visual attention (e.g. De Raedt & Ponjaert-Kristoffersen, 2001). The present study included measures of all of these abilities, enabling identification of the strongest predictors of driving ability.

Given the previous findings of significant relationships for health and functional measures with either crash involvement or on-road driving ability, it was hypothesised that the health and functional measures examined in the present study would be significantly correlated with performance on the on-road driving test. Specifically, it was predicted that a greater level of medical complaints (worse "general health") and greater medication use, especially use of medications potentially hazardous for driving, would both be associated with poorer driving test performance. It was also hypothesised that poorer functioning (in terms of mood, physical functioning, vision, mental status, speed of information processing, spatial memory and visual attention) would be associated with poorer driving test performance. Additionally, it was predicted that worse health and poorer functioning would be associated with poorer driving test performance independently of age. An analysis identifying the best predictors of driving test performance was also conducted, using a linear regression procedure.

The health and functional measures used in this study were: self-reported general health (based on self-reported medical conditions and the extent to which these conditions affect daily functioning), self-reported prescription medication use, use of medications potentially hazardous to driving, depressed mood, state anxiety, trait anxiety, neck mobility, visual acuity (left eye, right eye, binocular), contrast sensitivity (left eye, right eye, binocular), visual field (left, right, total), mental status, speed of information processing, spatial memory, and visual attention (reaction time and detection errors on the CVAT). Driving ability was measured using the weighted error score on the driving test. Full details for all of these measures are provided in Chapter 6.

8.2 Analyses

The relationships between variables were assessed using Pearson's Product Moment Correlations. Hierarchical regression analyses were used to test the strength of the significant relationships between driving performance and health and functional measures after controlling for age. All correlational analyses used an alpha level of .01 rather than the conventional .05, in order to guard against the increased likelihood of Type I errors resulting from multiple comparisons. This conservative alpha level was chosen ahead of using the Bonferroni method of correcting for multiple comparisons because the former allows for a consistent alpha level across the entire thesis rather than a different one for each set of analyses, and also because it has been argued that the Bonferroni method is too conservative when the number of comparisons gets too large (Jaccard & Wan, 1996). The size of correlations was also evaluated according to Cohen's (1992) effect size classifications. According to this system of classification, correlations of between .1 and .3 are "small" (accounting for between 1 and 9% of the variance), those between .3 and .5 are "medium-sized"(between 9 and 25% of the variance) and those over .5 are "large"(over 25% of the variance). The exploratory analysis to identify the best predictors of driving ability was conducted using a linear regression procedure, with a stepwise method of entry and the conventional entry criterion of alpha = .05. Only those variables found to be significantly correlated with driving test performance at the level of $p < .01$ were used in the regression analysis.

8.3 Results

8.3.1 Descriptive Statistics For Health/Functional Measures

8.3.1.1 Health Measures

The first part of the Driver Mobility Questionnaire asked participants to answer questions about specific medical conditions they might have had and to list any conditions they had that were not included in the questionnaire. It can be seen in Table 8.1 that over 83% of participants had at least one medical condition but few (less than 13%) had more than three. Participants were also asked to indicate, on a three point scale, the degree to which their medical conditions affected their daily functioning, in order to create a variable that took into account the severity of the conditions. When a variable was calculated that took these severity ratings into account, it ranged from zero to 12, with a mean of 2.57 and a standard deviation of 2.03. This suggests that the drivers in the sample were not strongly affected by the medical conditions they reported having. This variable ("general health") was used as an index of the degree to which the participants were affected by medical complaints.

Table 8.1

Number of medical conditions reported by participants (N = 104)

Number of conditions	Number of participants	Percentage
0	17	16.3
1	23	22.1
2	25	24.0
3	26	25.0
4	9	8.7
5	3	2.9
6	1	1.0
Total	104	100.0

The prevalence of specific medical conditions is provided in Table 8.2. For each medical condition, the table includes details about the number of participants who reported having it and the extent to which it affected their daily functioning. Despite not being included in the questionnaire, hypertension is included in the table because it was frequently mentioned by participants under "other medical conditions". The medical conditions most reported by participants were arthritis, hypertension and heart disease, with arthritis the condition most likely to have been affecting participants' daily functioning. Only one participant reported that any medical condition affected their daily functioning "a lot".

Table 8.2

Self-reported medical conditions and impact on daily functioning (N = 104)

Medical condition	Have the condition (%)	Functioning unaffected (%)	Functioning affected a bit (%)	Functioning affected a lot (%)
Glaucoma	7.7	5.8	1.9	-
Cataract	11.5	8.7	2.9	-
Macular degeneration	0.0	-	-	-
Diabetic retinopathy	0.0	-	-	-
TIA/Stroke[a]	10.6	8.7	1.9	-
Heart disease	15.4	13.5	1.9	-
Arrhythmia	9.6	8.7	1.0	-
Cancer	4.8	4.8	-	-
Arthritis	45.2	21.2	23.1	1.0
Alzheimer's Disease	1.0	1.0	-	-
Parkinson's Disease	1.0	-	1.0	-
Epilepsy	0.0	-	-	-
Diabetes	9.6	8.7	1.0	-
Sleep apnoea	2.9	1.9	1.0	-
Hypertension	30.8	30.8	-	-

[a] TIAs and strokes not suffered in the last year, as a recent stroke was an exclusion criterion

Participants were also asked to provide details of any prescription medications they took at least once a month. The number of medications used by participants is summarised in Table 8.3, where it can be seen that over 60% of participants reported using at least one prescription medication each month.

Table 8.3
Number of medications used at least once a month by participants (N = 104)

Number of medications	Number of participants	Percentage of participants
0	41	39.4
1	19	18.3
2	13	12.5
3	7	6.7
4	14	13.5
5	8	7.7
6	1	1.0
7	1	1.0
Total	104	100.0

The types of medications and the number of users are summarised in Table 8.4. Most of the medications are described in terms of the conditions they are designed to treat (e.g. "Hypertension"). The types of medication most commonly used by the participants were treatments for hypertension, followed by those used to treat heart problems and high cholesterol.

Table 8.4
Types of medications and number of users (N = 104)

Medication Type	Number of Participants	Percentage of Participants
Hypertension	28	26.9
Heart problems	15	14.4
Cholesterol	15	14.4
Arthritis	14	13.5
Calcium deficiency	13	12.5
Acid reflux/ulcer	12	11.5
Thyroid	9	8.7
Depression	6	5.8
Blood thinner	6	5.8
Diabetes	6	5.8
Hormone replacement	4	3.8
Asthma	3	2.9
Gout	3	2.9
Other	10	9.6

Given that many medications would have no effect on driving at all, the medications listed by participants were categorised according to whether they could potentially have a negative effect on driving (refer to section 6.2.2.1 for how this was done). Table 8.5 shows that the majority of participants did not regularly use a medication that could negatively affect driving. Furthermore, the majority (30 of 44) who did use a medication that could affect driving used only one.

Table 8.5
Number of medications potentially affecting driving that were used regularly by participants (N = 104)

Number of medications	Number of participants	Percentage of participants
0	60	57.7
1	30	28.8
2	6	5.8
3	7	6.7
4	1	1.0
Total	104	100.0

The types of medications categorised as potentially affecting driving and the number of cases of their use are shown in Table 8.6. Note that where one participant uses more than one medication to treat the same problem, each of these medications is included in the table as a separate case of its use, meaning that the number of cases of use of a medication in Table 8.6 may exceed the number of participants taking a medication for that condition reported in Table 8.4. Among the medications potentially affecting driving, the most common were those used to treat hypertension, heart problems, acid reflux or ulcers, and depression.

8.3.1.2 Functional Measures

Descriptive statistics for the functional measures are provided in Table 8.7, with the exception of visual acuity scores (ordinal data more suited to presentation in terms of frequencies, see Table 8.8) and the Computerised Visual Attention Test scores (see Table 8.9).

Table 8.6
Types of medications potentially affecting driving used by participants (N = 104)

Medication Type	Number of Cases of Use	Percentage of Cases
Hypertension	20	29.9
Heart problems	18	26.9
Acid reflux/ulcer	8	11.9
Depression	6	9.0
Arthritis	3	4.5
Gout	2	3.0
Calcium deficiency	1	1.5
Asthma	1	1.5
Other	8	11.9
Total	67	100.0

There were low levels of depressed mood among the sample, with only eight participants scoring above nine (suggestive of mild depression) and none scoring above 19 (suggestive of severe depression) (Spreen & Strauss, 1997). There were also low levels of anxiety with the means for state and trait anxiety both being below norms for those aged 50 to 69 (approximately 35 for both types of anxiety) (Speilberger, 1983). The contrast sensitivity levels were slightly lower than norms presented in Mantyjarvi and Laitinen (2001) but this is probably due to an older average age of the sample in the present study (M = 74.2, SD = 6.3 versus M = 67.8, SD = 4.9). There were very few deficits in horizontal visual field among the sample, with the majority of participants recording the maximum visual field (90°) for both eyes. Some degree of limited neck mobility was recorded for almost all of the drivers in the sample, with only 13 of the 104 drivers recording a maximum neck mobility score of 180 degrees. There was little evidence of possible dementia in the sample, with only one participant recording a score of less than 24 on the MMSE, the cut-off for suspected dementia (Lezak, 1995). The mean for the Symbol Digit Modalities test (36.9) approximates the norm for those aged 65 to 74 of 37.4 (Lezak, 1995), as does that for Total Spatial Span (13.3 compared to the norm of 13) (Wechsler, 1997).

Table 8.7

Functional test performance (N = 104)

Test	Mean	*SD*	Range of Possible Scores
Depressed mood			
Geriatric Depression Scale	3.9	3.2	0 - 30
Anxiety			
State Anxiety	31.7	8.1	20 - 80
Trait Anxiety	31.0	7.6	20 - 80
Vision			
Contrast sensitivity, right	1.61	0.15	0 - 2.25
Contrast sensitivity, left	1.61	0.13	0 - 2.25
Contrast sensitivity, binocular	1.77	0.14	0 - 2.25
Visual field, left	86.4	7.5	0 - 90
Visual field, right	86.7	7.7	0 - 90
Total visual field	173.1	12.3	0 - 180
Physical functioning			
Total neck mobility	139.2	25.6	0 - 180
Mental status			
3MS	94.7	5.3	0 - 100
MMSE	28.6	1.7	0 - 30
Speed of info processing			
Symbol Digit	36.9	10.3	0 - 110
Spatial memory			
Total Spatial Span	13.3	3.1	0 - 32

Note. 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination

The frequencies for visual acuity scores are provided in Table 8.8. It can be seen that only one person recorded binocular visual acuity worse than 6/12. This is consistent with the large Australian study by Ivers et al. (1999), which reported few drivers aged 50 or more with acuity worse than 6/12.

Table 8.8

Visual acuity frequencies (N = 104)

Visual acuity	Left eye[a]	Right eye	Binocular
6/5	22	27	56
6/6	32	25	24
6/9	31	30	19
6/12	12	14	4
6/18	5	4	1
6/24	1	3	-
6/36	-	-	-
6/60	-	1	-
Total	103	104	104

[a] The total for the left eye is 103 rather than 104 because one participant had a glass left eye. The right eye visual acuity for this participant was taken as his binocular acuity.

In addition to the standardised functional tests, the participants completed the Computerised Visual Attention Test (CVAT). The CVAT produced reaction time and detection error scores for two different targets (Xs in the central visual field for the primary task and cars in the peripheral visual field for the secondary task) in both single and dual task conditions (divided attention manipulation), and with and without visual distracters for the secondary task (selective attention manipulation). Table 8.9 provides the means and standard deviations for median reaction times and detection error scores.

Table 8.9
Median reaction times and detection error percentages on the CVAT (N = 104)

	Reaction times		Detection errors	
Test condition	Mean (ms)	*SD*	Mean (%)	*SD*
Single task				
Primary	433.1	44.3	0.3	1.1
Secondary, no visual distracters	414.3	52.9	<0.1	0.4
Secondary, visual distracters	537.1	72.1	1.8	3.7
Dual task				
Primary, no visual distracters on secondary	467.3	53.6	2.5	4.8
Secondary, no visual distracters	481.5	68.5	0.4	1.6
Primary, visual distracters on secondary	494.0	51.7	5.1	5.3
Secondary, visual distracters	635.6	111.6	5.5	8.3

Note. CVAT = Computerised Visual Attention Test

The three reaction time scores for the primary task shown in Table 8.9 were analysed with a repeated measures analysis of variance and found to differ significantly ($F_{(2,206)} = 189.6$, $p = .000$). Similarly, the three detection error scores for the primary task were also found to be significantly different ($F_{(1,193)} = 50.0$, $p = .000$). This suggests that the extra attentional load of the different secondary task conditions (no secondary task, secondary task without visual distracters, secondary task with visual distracters) increased reaction times and detection errors for the primary task.

The four reaction time scores for the secondary task shown in Table 8.9 were analysed with a repeated measures analysis of variance using two within subjects factors: single or dual task condition, and with or without visual distracters. Significant differences were found for the dual task manipulation ($F_{(1,103)} = 221.8$, $p = .000$), the visual distracters manipulation ($F_{(1,103)} = 573.9$, $p = .000$) and the interaction between the two ($F_{(1,103)}$ = 19.3, p = .000). A similar procedure was used for detection error scores and, again, there were significant effects for the dual task manipulation ($F_{(1,103)}$ = 23.8, p = .000), for the visual distracters manipulation ($F_{(1,103)}$ = 52.1, p = .000) and for the interaction between the two manipulations ($F_{(1,103)}$ = 19.6, p = .000). Inspection of the means in Table 8.9 indicates that reaction times and detection errors for the secondary task were greater in the dual task rather than the single task conditions (divided attention effect), were greater in the conditions featuring visual distracters than in the conditions without (selective attention effect), and that the dual task and visual distracter manipulations interacted to increase both reaction time and detection errors.

8.3.2 Descriptive Statistics for Driving Test Performance

Of the 104 participants, 90 completed the driving test. Of these 90 participants, 82 were from the general community and eight were referrals. Ten of the community participants chose not to undergo the driving assessment, while three referral participants and one community participant were not able to complete the driving test and so their results for the driving component had to be discarded. The outcomes of the 90 driving tests, in terms of recommendations by the assessor, were 68 passes (75.6%), eight passes with recommendations for lessons (8.9%) and 14 failures (15.6%).

Scores were calculated for interventions by the driving instructor, hazardous errors and habitual errors. The mean number of driving instructor interventions per test was 1.1 (*SD* = 1.7), the mean number of hazardous errors was 10.5 (*SD* = 10.9) and the mean number of habitual errors was 54.0 (*SD* = 17.5). These results show that interventions by the driving instructor were rare and that hazardous errors were a lot less common than habitual errors. There was also greater variation in driving instructor interventions and hazardous errors than in habitual errors.

To create a continuous variable for use as the outcome measure from the driving test, a total error score for the test was calculated, with different weightings applied to the different types of errors . As indicated in section 6.2.2.3, the equation for the calculation of this weighted error score was:

10 (driving instructor intervention) + 5 (hazardous errors) + habitual errors

The scores on this measure ranged between 18 and 443, with a mean of 117.6 (*SD* = 78.3). It can be seen in a scatterplot of the scores for this variable by age and referral source (Figure 8.1) that there was considerable overlap between the driving scores of DARS referrals and drivers from the general community, with many general community drivers scoring more poorly than half of the referral group. This demonstrates the acceptability of analysing the results for the sample as a whole, rather than for two separate groups.

8.3.3 Relationships with Age

This section provides details of the relationships between the health, functional and driving measures and age. First, Pearson's correlation coefficients were calculated between age, and general health and medication use. The correlation between age and general health was .14 ($p = .163$), between age and medication use was .05 ($p = .626$), and between age and use of medications potentially hazardous for driving was .09 ($p = .353$). Therefore, contrary to expectations, there were no significant correlations between age and general health or medication use among the sample of older drivers.

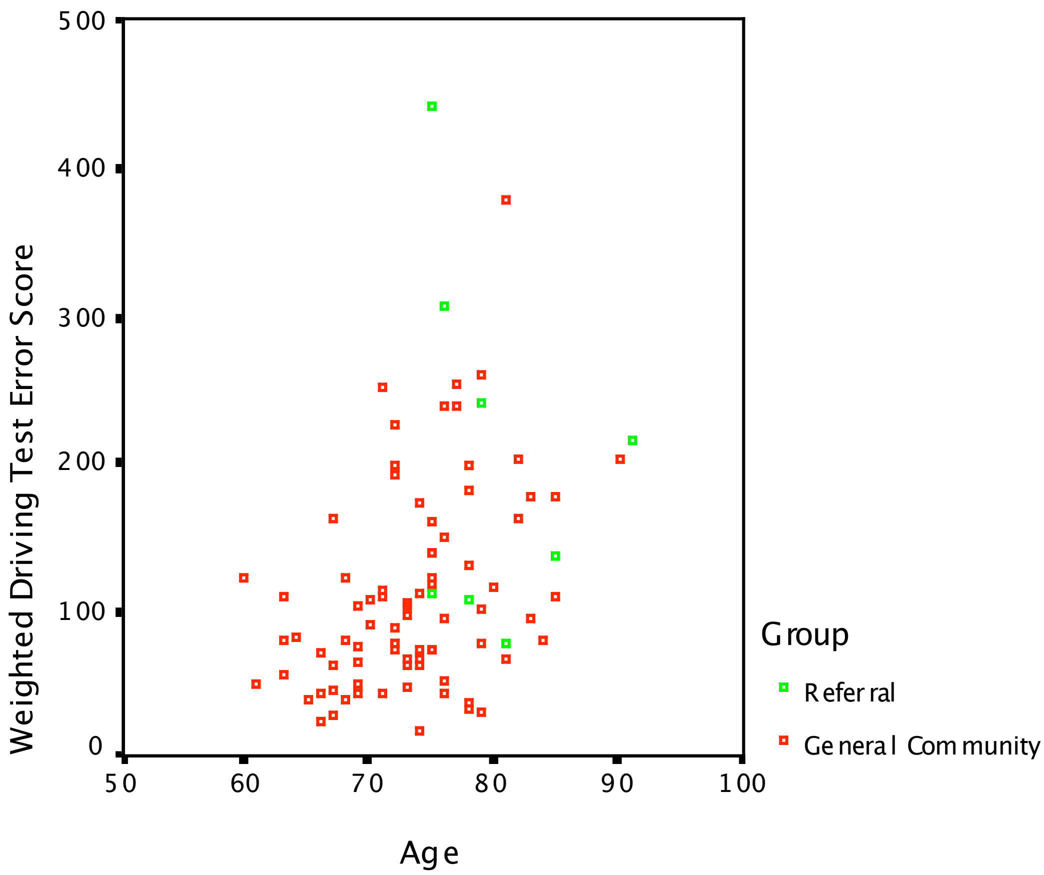

Figure 8.1. Scatterplot showing weighted error scores on the driving test, by age and participant group.

Correlations between age and standard functional measures are shown in Table 8.10, where it can be seen that a number of functional measures were correlated with age. Increased age was significantly associated with decreased right eye and binocular visual acuity, decreased right eye and binocular contrast sensitivity, and poorer performance on the Symbol Digit Modalities test. The two right eye vision scores shared small correlations with age, while the remaining significant correlations were medium-sized. Age was not found to correlate significantly with depressed mood, anxiety, neck mobility, visual field, mental status, or Spatial Span.

Table 8.10

Correlations between standard functional tests and age (N = 104)

Test	Correlation with age
Depressed mood	
Geriatric Depression Scale	.13
Anxiety	
State Anxiety	.01
Trait Anxiety	.02
Physical functioning	
Total neck mobility	-.23
Vision	
Visual acuity, left eye	.24
Visual acuity, right eye	.28*
Visual acuity, binocular	.37**
Contrast sensitivity, left eye	-.24
Contrast sensitivity, right eye	-.28*
Contrast sensitivity, binocular	-.44**
Visual field, left	.03
Visual field, right	-.18
Total visual field	-.09
Mental status	
3MS	.01
MMSE	.09
Speed of info processing	
Symbol Digit	-.38**
Spatial memory	
Total Spatial Span	-.19

Note. 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination
* $p < .01$, ** $p < .001$

The relationship between age and visual attention was examined by determining correlations between age and both median reaction time and target detection errors on the CVAT, which are shown in Table 8.11. Three of the seven reaction time measures were positively correlated with age, indicating a decline in performance with increased age. These tasks were the two requiring detection of Xs (primary task) in dual task conditions and the task requiring detection of cars (secondary task) in the presence of visual distracters in the dual task condition. The correlations were in the small to medium range. For detection errors, correlations with age were only calculated for scores in the dual task conditions because detection errors in the single task conditions were not found to be reliable (see Chapter 7). Two of the four remaining measures were significantly correlated with age, with increasing age associated with a higher number of target detection errors. Significant correlations were found for the detection of Xs (primary task) and detection of cars (secondary task) in the dual task condition featuring visual distracters on the secondary task. These correlations were both in the small range.

Table 8.11

Correlations between age and CVAT median reaction times and detection errors (N = 104)

Test condition	Correlations between CVAT scores and age Reaction times	Detection errors
Single task		
Primary	.18	
Secondary, no visual distracters	.09	
Secondary, visual distracters	.25	
Dual Task		
Primary, no visual distracters on secondary	.25*	.11
Secondary, no visual distracters	.18	-.06
Primary, visual distracters on secondary	.26*	.27*
Secondary, visual distracters	.36**	.27*

Note. CVAT = Computerised Visual Attention Test

* $p < .01$, ** $p < .001$

Finally, the weighted error scores on the driving test were found to share a significant, medium-sized correlation with age ($r = .37$, $p = 000$) indicating that increased age was associated with a greater number of errors on the on-road driving test. This significant correlation, in addition to those between age and a number of functional variables, indicates that the confounding effects of age should be controlled for in any analyses of the relationships between functional measures and driving test performance.

8.3.4 The Relationship Between Health and Functional Measures, and Driving Performance

The relationship between medical conditions and driving ability was assessed by calculating Pearson's correlation coefficients between the "general health" variable, based on diagnosed medical problems and associated self-reports of effects on daily functioning, and the weighted error score on the driving test. This correlation was found to be .21, which was only approaching significance ($p = .045$).

The relationship between prescription medication use and driving was also examined, both for overall medication use and use of medications potentially hazardous for driving. The correlation between medication use and driving test performance was not significant ($r = .19$, $p = .075$), while that between use of medications potentially hazardous to driving and driving test performance only approached significance ($r = .22$, $p = .038$).

The relationship between the functional measures and driving test performance was also assessed with correlations (refer to Table 8.12). It can be seen that left eye and binocular contrast sensitivity, the Symbol Digit Modalities test, and the Spatial Span subtest of the WMS-III were all significantly correlated with driving test performance. Each of these significant correlations was in the expected direction, indicating that driving test performance was worse for those with poorer contrast sensitivity, speed of information processing and spatial memory. The correlations were all medium-sized. Correlations between driving test performance and the Geriatric Depression Scale, binocular visual acuity, contrast sensitivity in the right eye and the 3MS were all small but approached significance ($p < .05$).

As age was related to driving test performance, assessments were made of the strength of the relationships between functional measures and driving test performance, independent of age effects. For each functional measure that was significantly correlated with driving test performance, a hierarchical regression analysis was performed, with driving test performance as the dependent variable, and age (entered at step 1), and each functional measure (entered at step 2) as predictor variables. The results of these hierarchical analyses are shown in Table 8.13. It can be seen that binocular contrast sensitivity, Symbol Digit and Total Spatial Span no longer made significant contributions to the prediction of driving test performance once age effects had been controlled, although Total Spatial Span approached significance ($p = .014$).

Only left eye contrast sensitivity made a significant contribution to the prediction of driving test performance independently of age.

Table 8.12

Correlations between functional tests and driving performance (n=90)

Test	Correlation with driving
Depressed mood	
Geriatric Depression Scale	.24
Anxiety	
State Anxiety	.09
Trait Anxiety	.20
Physical functioning	
Total Neck Mobility	-.19
Vision	
Visual acuity, left eye	.19
Visual acuity, right eye	.12
Visual acuity, binocular	.25
Contrast sensitivity, left eye	-.36**
Contrast sensitivity, right eye	-.22
Contrast sensitivity, binocular	-.33*
Visual field, left	.06
Visual field, right	.02
Total visual field	.05
Mental status	
3MS	-.26
MMSE	-.19
Speed of info processing	
Symbol Digit	-.32*
Spatial memory	
Total Spatial Span	-.30*

Note. 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination

* $p < .01$, ** $p < .001$

Table 8.13

Results of hierarchical regression procedures examining the contributions of functional measures to the prediction of driving performance, after controlling for age (n = 90)

Variables	*B*	Adj R^2	ΔR^2	ß	*t*
Age	3.69	.121	.121	.290	2.91*
Contrast sensitivity, left eye[1]	-172.44	.187	.066	-.283	-2.85*
Age	3.53	.125	.125	.278	2.59*
Contrast sensitivity, binocular	-114.64	.153	.028	-.212	-1.98
Age	3.60	.125	.125	.284	2.65*
Symbol Digit	-1.63	.150	.025	-.203	-1.90
Age	4.10	.125	.125	.323	3.30*
Total Spatial Span	-6.27	.174	.049	-.245	-2.51

[1] $n = 89$, as one participant had a glass left eye

* $p < .01$, ** $p < .001$

Correlations were also used to determine the relationships between visual attention and driving test performance. Table 8.14 shows the correlations between driving test performance and CVAT reaction times and detection errors. Reaction time scores for the CVAT were all significantly related to driving test performance, with correlations of medium size. The correlations were all in the expected direction, indicating that those with longer reaction times performed less well on the driving test. For detection errors, again only dual task performance was analysed because of the low reliability of single task detection error scores (see Chapter 7). The only significant correlations with driving test performance were for detection of both Xs (primary task) and cars (secondary task) in the dual task condition, with visual distracters on the secondary task (the subtest requiring divided and selective attention). Both of these correlations were medium-sized and positive, indicating worse driving test performance by those who missed more targets on the CVAT.

Table 8.14
Correlations between driving performance, and CVAT median reaction times and detection errors (n = 90)

Test condition	Median reaction times correlations with driving	Detection errors correlations with driving
Single task		
Primary	.38**	
Secondary, no visual distracters	.35*	
Secondary, visual distracters	.43**	
Dual Task		
Primary, no visual distracters on secondary	.33*	.24
Secondary, no visual distracters	.32*	.02
Primary, visual distracters on secondary	.30*	.32*
Secondary, visual distracters	.46**	.36**

Note. CVAT = Computerised Visual Attention Test
$*p < .01$, $**p < .001$

In order to gauge whether these relationships were independent of the effects of age, hierarchical regression analyses were conducted, with the weighted error score on the driving test as the dependent variable, and age (entered at step 1), and CVAT scores (entered at step 2) as predictor variables. Table 8.15 shows the results of these analyses, with all reaction time measures making significant, independent contributions to the prediction of driving test performance beyond the effects of age, except for reaction times to the Xs (primary task) in the dual task conditions. Detection errors significantly predicted driving test performance for the secondary task (in the dual task condition, with visual distracters) but only approached significance for the primary task in the same subtest (dual task, visual distracters on the secondary task). Overall, these results suggest that visual attention, as measured by performance on the CVAT, significantly predicts driving test performance independently of age, particularly when using the reaction time scores.

To summarise the correlational analyses, the functional measures that were significantly related to driving test performance and made a significant contribution to its prediction independent of age were: left eye contrast sensitivity, reaction time scores on the CVAT for all secondary tasks and also for the primary task in the single task condition, and CVAT detection errors on the secondary task in the dual task condition with visual distracters. The variables that were significantly correlated with driving performance but did not significantly predict driving performance after controlling for age were: binocular contrast sensitivity, Symbol Digit Modalities Test, Total Spatial Span, primary task reaction times in the two dual task conditions of the CVAT, and primary task detection errors in the dual task condition with visual distracters on the secondary task of the CVAT. The relationships between a number of the remaining variables and driving test performance only approached significance prior to controlling for age effects. These were: general health, use of medications potentially hazardous to driving, the Geriatric Depression Scale, binocular visual acuity, contrast sensitivity in the right eye, the 3MS and primary task detection errors in the dual task condition without visual distracters on the CVAT secondary task. All of the significant correlations between driving test performance, and health and functional measures were small to medium in size, with no correlations of .50 or more.

Table 8.15

Results of hierarchical regression procedures examining the contributions of median reaction times and detection errors on the CVAT to the prediction of driving performance, after controlling for age (n = 90)

Variables	*B*	Adj R^2	ΔR^2	ß	*t*
Reaction times, single task					
Age	3.81	.125	.125	.300	3.12*
Primary	0.57	.212	.087	.315	3.27*
Age	4.63	.125	.125	.364	3.95**
Secondary, no visual distracters	0.57	.241	.116	.352	3.81**
Age	3.64	.125	.125	.286	3.03*
Secondary, visual distracters	0.40	.244	.119	.365	3.86**
Reaction times dual task					
Age	3.83	.125	.125	.301	3.02*
Primary, no visual distracters on the secondary task	0.38	.173	.048	.247	2.48
Age	4.21	.125	.125	.331	3.45*
Secondary, no visual distracters	0.34	.193	.068	.279	2.91*
Age	3.93	.125	.125	.310	3.07*
Primary, visual distracters on the secondary task	0.33	.158	.033	.213	2.11
Age	3.17	.125	.125	.250	2.58
Secondary, visual distracters	0.28	.247	.122	.378	3.91**
Detection errors, dual task					
Age	3.70	.125	.125	.291	2.79*
Primary, visual distracters on the secondary task	3.08	.154	.029	.210	2.01
Age	3.72	.125	.125	.293	2.98*
Secondary, visual distracters	2.81	.192	.067	.285	2.89*

Note. CVAT = Computerised Visual Attention Test; Primary = Primary task; Secondary = Secondary task
* $p < .01$, ** $p < .001$

In order to determine which variables were the best independent predictors of driving test performance, a linear regression procedure was used, with driving test performance as the dependent variable and all of the measures that were significantly correlated with driving test performance ($p < .01$) as predictor variables. Age was also included as a predictor variable, enabling a test of the hypothesis that age is related to deficits in driving only because it is related to deficits in functioning that are, in turn, related to driving deficits. A stepwise procedure was used for the regression analysis, with the level of significance required for entry into the equation set at $p < .05$. The results of this procedure are summarised in Table 8.16, and a table of inter-correlations between candidate predictor variables is provided in Appendix 8.

As shown in Table 8.16, the variables most predictive of driving test performance were reaction time for the secondary task in two different conditions (dual task with visual distracters and single task without visual distracters), binocular contrast sensitivity, and total spatial span. The model featuring all four variables accounted for 34% of the variance (Adjusted R squared) in the driving measure (the weighted error score on the driving test).

Table 8.16
Results of a linear regression procedure predicting driving test performance, using functional measures as predictor variables (n = 90)

Variables in the model (order of entry)	*B*	Adj R^2	ΔR^2	ß	*t*
Reaction time for car detection, dual task condition, with visual distracters[1]	0.17	.21	.21	.236	2.30*
Binocular contrast sensitivity	-128.40	.25	.04	-.237	-2.63*
Total Spatial Span	-6.41	.29	.04	-.248	-2.74**
Reaction time for car detection, single task condition, without visual distracters[1]	0.42	.34	.05	.255	2.64*

[1] Measure taken from the Computerised Visual Attention Test
* $p < .05$, ** $p < .01$

8.4 Discussion

This chapter examined the relationships between health (general health and medication use) and functional measures (mood-related variables, physical functioning, vision, mental status, speed of information processing, spatial memory, and visual attention), and driving ability (performance on an on-road driving test). This analysis was conducted to allow for a later comparison with the health and functional measures found to be related to older driver self-regulation (Chapter 11). Prior to this, the results of these analyses can be compared with those of previous studies investigating the relationships between health and functional measures, and driving ability among older drivers.

8.4.1 Relationships Between Health and Functional Measures and Driving Ability

General health and driving ability were not strongly related, contradicting the suggestions of some authors (Dobbs et al., 1998; Klavora & Heslegrave, 2002; Marottoli, 2002; Wallace & Retchin, 1992; Waller, 1992) that being affected by a combination of different medical conditions increases the risk of driving problems among older drivers. However, as this variable was based on self-ratings of the effects of medical conditions on daily functioning, it is possible that some participants failed to report all of their medical conditions or understated the extent to which their daily functioning was affected by them. This notwithstanding, the findings suggest that it is more important to evaluate functional abilities than medical conditions when attempting to predict the driving abilities of older drivers. The importance of functional abilities to driver re-licensing and assessment has been advocated previously (Marottoli et al., 1998; OECD, 2001; Sims et al., 1998; Wallace & Retchin, 1992; Waller, 1992; White & O'Neill, 2000) and the findings of the present study provide additional empirical support to this view.

The number of medications used by the drivers was not significantly correlated with driving, consistent with a previous study by Foley et al. (1995) which found no relationship between medication use and crash involvement among older drivers. Use of medications potentially hazardous to driving (those that can cause central nervous system impairment, drowsiness, or dizziness) was also found to be unrelated to driving ability, although the correlation approached significance. These results suggest that medication use is not strongly related to driving ability but caution must be exercised in accepting this conclusion because the information used in this study was self-reported. A more accurate source of information concerning medication use (e.g. medical records) may have produced different results. Despite the weak relationships found here, attention still needs to be given to the medications taken by older drivers and effort should be directed towards minimising the use of medications that could produce side-effects detrimental to driving. It also needs to be remembered that untreated medical conditions may have a greater effect on functional abilities, and hence driving, than the medications used to treat them (Marottoli, 2002).

None of the measures of participant mood (depressed mood, state and trait anxiety) were significantly related to driving ability. Again, some caution must be exercised when interpreting the lack of a relationship between depressed mood and driving ability, as the sample included healthy participants who generally had low levels of depressive symptoms. Only seven of the 90 participants recorded scores above the cut-off for mild depression on the Geriatric Depression Scale. It could be that depressed mood would be found to be related to decrements in driving ability using a sample including more participants with higher levels of depressive symptoms. Previous studies by Sims et al. (2000) and Foley et al. (1995) have found significant relationships between depressive symptoms and crash involvement, whereas a recent study by Garrity and Demick (2001) found no association between depression and on-road driving performance among older drivers.

Consistent with expectations, there were significant correlations between driving ability and contrast sensitivity. Visual acuity was not found to be related to driving ability, although the relationship approached significance. Visual field also was not found to be related to driving ability. A more detailed and technologically advanced measure of participants' visual fields (e.g. Humphrey Field Analyzer; Optifield II) may be necessary, rather than a simple horizontal visual field measure, to adequately measure this variable. Binocular contrast sensitivity was also among four variables that were found in a regression procedure to make significant, independent contributions to the prediction of driving ability. The finding that contrast sensitivity is more strongly related to the on-road driving ability of older drivers than other simple vision measures replicates the results of previous studies (Janke & Eberhard, 1998; Wood, 2002a) and suggests that vision assessments for re-licensing of older drivers should include contrast sensitivity, rather than visual acuity, as a simple vision measure. The Australian guidelines for assessment of fitness to drive (Austroads, 2001) set limits for visual acuity and visual field but not for contrast sensitivity.

No relationship was found between neck mobility and driving ability in the present study, contradicting the findings of McPherson et al. (1988). It was consistent, however, with a number of studies that have failed to find a significant relationship between neck mobility and measures of on-road driving performance (Odenheimer et al., 1994; Staplin et al., 1998b; Tarawneh et al., 1993). It may be that only profound decrements in physical functioning lead to poorer driving ability.

Mental status, as measured by the original Mini Mental State Examination (MMSE), was not related to driving ability, and the relationship between driving and the more recent, expanded version of the test (3MS) only approached significance. The 3MS was chosen as a measure of mental status for this study because it generates a wider range of scores than the MMSE, with less attenuation by ceiling effects (Teng & Chui, 1987). Also, the 3MS includes additional questions (date and place of birth, word fluency, similarities, and delayed recall of words) that are intended to assess functions important for differentiating between those who are healthy and those affected by cognitive impairment. However, the relationship between the 3MS and driving ability was weak, suggesting that mental status may be more important for drivers with dementia, than for healthy, community-dwelling older drivers. Mental status has often been linked with crash involvement or poorer on-road driving performance in previous studies, especially in those including drivers with dementia (Clark et al., 2000; Cushman, 1996; Fitten et al., 1995; Johansson et al., 1996; Odenheimer, 1993; Rizzo et al., 2001) while those studies not finding any relationship have generally been based on only a small sample (Lesikar et al., 2002) or have had an attenuated range of scores (Janke, 2001).

As predicted, speed of information processing, as assessed by the Symbol Digit Modalities Test, was significantly related to driving ability. However, this was not the case after controlling for age. Information processing is known to slow with age (Salthouse, 1985) and it may be that, in a sample of drivers with little cognitive impairment, this measure largely assessed age-related slowing in processing. Thus, it may be that Symbol Digit performance does not provide a greater indication of likely driving ability beyond that given by age.

Spatial memory, as predicted, was related to driving ability, with Total Spatial Span sharing a moderate relationship with performance on the on-road driving test. This relationship remained significant after controlling for the effects of age. This is consistent with studies by de Raedt and Ponjaert-Kristoffersen (2000) and Lundberg et al. (1998), which found that indices of visuospatial memory were related to on-road driving test performance and crash involvement, respectively. Total Spatial Span was also one of the four variables that predicted driving ability in a regression procedure.

As predicted, the CVAT measures were related to driving, with all seven reaction time measures and two detection error scores correlating with driving ability. After controlling for the effects of age, five reaction time measures and one of the detection error scores remained significant predictors of driving ability. Furthermore, when a linear regression was conducted to identify the best predictors of driving ability, two of the four variables identified were reaction time measures from the CVAT: the measure assessing selective and divided attention for stimuli in the peripheral visual field (the secondary task in the dual task condition with visual distracters), and the measure assessing simple visual attention for stimuli in the peripheral visual field (the secondary task in the single task condition without visual distracters). The fact that these two measures predicted driving ability highlights the importance for driving of being able to quickly detect stimuli in the visual periphery. The importance of visual attention for safe driving by older drivers is consistent with the findings of a large number of previous studies (Clark et al., 2000; Cushman, 1996; De Raedt & Ponjaert-Kristoffersen, 2000; Duchek et al., 1998; Haegerstrom-Portnoy et al., 1999; Hunt et al., 1993; Janke, 2001; Lundqvist et al., 2000; Odenheimer et al., 1994; Owsley et al., 1998; Richardson & Marottoli, 2003).

Previous claims that functional performance is more important than age in determining driving ability (Cushman, 1996; Hakamies-Blomqvist, 1996; Staplin et al., 1998b) were supported by the findings of the present study, as age was not among the variables that best predicted performance in the on-road driving test. The two reaction time measures, contrast sensitivity and Spatial Span entered the regression equation prior to age, and once the effects of these variables had been taken into account, age no longer made an independent contribution to the prediction of driving ability. This is an important finding because it reinforces the view that age-based mandatory testing of older drivers is an unsupportable re-licensing policy. Age is mainly associated with declines in driving ability because of its relationship with functional declines that, in turn, are related to driving ability. Retesting of the driving capabilities of older drivers should be undertaken only when there is evidence for declines in functioning, not because a driver has reached a particular age.

It is also important to note that the four variables that entered the regression equation explained only 34% of variance in driving ability. This demonstrates the difficulty of developing measures for identifying at-risk older drivers in the general community (Hakamies-Blomqvist, 2003), and also the complex nature of the driving task.

Previous studies utilising regression procedures to predict performance in on-road driving tests have often been based on samples with a greater proportion of drivers with cognitive impairments or who were referred for an assessment of their driving (e.g. Cushman, 1996; De Raedt & Ponjaert-Kristoffersen, 2000; Duchek et al., 1998; Janke, 2001; Lundqvist et al., 2000). The proportion of variance in driving test scores explained by test measures in these studies has ranged between 15 and 67%. Tarawneh (1993) assessed drivers recruited from the general community and found that five tests accounted for 45% of variance in driving performance scores. Janke (2001) reported the results of two studies predicting driving ability. In one of these, the performance in on-road driving tests of a sample of referrals was examined and a model including age, sex and the results of two functional tests accounted for 50% of variance in driving test scores. In the other study, examining the performance of healthy volunteers only, the amount of variance in driving scores accounted for by regression equations was 20% or less. Therefore, it appears that attempts to predict driving ability tend to be more successful when assessing drivers with a greater likelihood of impairment. Less variance is accounted for in studies of healthy community-dwelling volunteers.

8.4.2 Limitations

Turning to the limitations of the study, it must be recognised that the on-road driving test has not, itself, been validated. Although on-road driving test performance is a good outcome measure for a study of this type, it has not been established that the test methods utilised in this study are predictive of driving ability when not in a test situation, or of future crash involvement. This limitation applies commonly to studies using on-road tests of driving ability. However, the assessments of on-road driving performance used in this study were very detailed and used the expertise of both occupational therapists and professional driving instructors. Also, there are problems with using crash involvement as an indicator of difficulties with driving. One problem is that crashes are rare events, and so drivers with an increased risk of crashing may not be involved in a crash during the study period. To illustrate this, Stutts et al. (1998) stated that less than six percent of licensed drivers crash in any given year. If a factor could be found that identified drivers who had double or triple the normal risk of crashing, only 10 to 20% of the drivers affected by this factor would be expected to crash in the forthcoming year, while 80 to 90% would be crash-free (Stutts et al., 1998). A second problem is that crashes are multi-determined events. That is, the occurrence of a crash is rarely caused by only one factor but, rather, by the simultaneous effects of a number of factors that increase crash risk, many of which are independent of driver error.

One common criticism of the use of on-road driving tests, in either re-licensing assessments or research, is that they do not assess driver ability in emergency situations. There may be drivers who have deficits in functioning and ability that are not serious enough to affect their driving ability in normal driving conditions but which may markedly affect their ability to respond in the emergency situations that can lead to crashes (Hunt et al., 1993; Maycock, 1997; Rizzo et al., 2001; Schlag, 1993; Waller, 1992). This objection to road tests ignores the fact that good driving is likely to lead to the avoidance of emergency situations. Good drivers are less likely to need to use emergency braking or steering because they drive cautiously and also use experience to recognise potentially hazardous situations in advance. Also, in regard to the use of on-road tests for re-licensing procedures, it could be considered unfair to expect older drivers to demonstrate the ability to respond to emergency situations, given that new drivers, to obtain a licence, are not required to demonstrate this ability.

A second limitation of the present study is that it uses a cross-sectional design. It may be that a longitudinal study of within-participant declines in abilities would produce different results. Another limitation is the that the results may have been affected by volunteer bias, such that participants were more likely to be healthy and high-functioning. The inclusion of more participants who were referred for a driving assessment would have broadened the range of abilities that were sampled but it is still likely that, among the general community group, volunteers would have been more likely to be those who were confident about their ability to pass an on-road driving assessment. Lee et al. (2003, p802) described this problem for driving studies as "unavoidable" and said that random sampling is "neither possible nor practical". A final limitation was that the measures of health and medication use were self-reported and so their accuracy cannot be guaranteed.

CHAPTER 9: DRIVING ATTITUDES AND BEHAVIOUR

9.1 Introduction

Self-regulation of driving behaviour involves responding to self-assessed declines in driving ability with avoidance of difficult driving situations (Charlton et al., 2001). The literature on self-regulation of driving behaviour by older drivers was described in section 4.3. It was noted that older drivers most frequently report that they avoid driving at night (e.g. Charlton et al., 2001), and also avoid inclement weather, busy traffic, high speed roads, unfamiliar roads, and performing turns across oncoming traffic (Eberhard, 1996; Holland & Rabbitt, 1994; Stutts, 1998). Older drivers have additionally reported driving more slowly and taking shorter trips (e.g. Forrest et al., 1997). Moreover, this self-regulation is often associated with the perceived difficulty of these driving situations (e.g. Rabbitt et al., 2002), and also with increased age, female gender, and retirement (e.g. Burns, 1999). It is unclear whether previous crash involvement leads to self-regulation, as earlier studies have produced inconsistent findings (Ball et al., 1998; Daigneault et al., 2002a). A number of barriers to self-regulation have also been identified by Stalvey and Owsley (2000), with drivers reporting a need to maintain high levels of driving because of inadequate public transport, the lack of friends or relatives to drive them when needed, and the desire to maintain their active lifestyles.

One of the aims of the present study was to determine the extent to which a sample of drivers in South Australia practised self-regulation of driving. No study in Australia has investigated the driving practices of older drivers in as much depth as was provided by the Driver Mobility Questionnaire described in section 6.2.2.1 (for a full copy refer to Appendix 6A). The questionnaire included questions about:

- preferred mode of travel;

- preferred driving speed compared to other traffic;
- whether the participant had ever been advised to restrict or cease his or her driving and, if so, by whom;
- perceived driving ability, vision, and ability to carry out more than one task simultaneously;
- how much driving the participant did, in terms of the number of days driven per week, trips taken per week, and kilometres driven per week;
- whether the participant had reduced his or her driving in the last ten years and, if so, for what reason;
- level of confidence when driving in various difficult situations (e.g. in the rain at night);
- how many crashes and police-reported crashes the participant had been involved in during the previous five years;
- how many times the participant had been pulled over by the police and the number of traffic violations he or she had been charged with in the previous five years;
- the geographical area over which the participant drove (e.g. local neighbourhood, interstate);
- the extent to which the participant avoids difficult driving situations;
- perceived barriers to reductions in driving;
- and the participant's perceived ability to organise his or her life so that a reduction in driving in difficult situations would be possible (regulatory self-efficacy).

Responses to this questionnaire allowed an examination of the extent of self-regulation among older drivers, its associations with perceived abilities and confidence, and whether there were factors that were reducing the likelihood of self-regulation. Based on previous research, it was hypothesised that increased age and female gender would be associated with lower self-ratings of abilities (driving, vision, dual task), lower driving space (geographical area in which driving is done), reduced driving exposure (amount of driving done), lower confidence in difficult driving situations, and greater avoidance of difficult driving situations (greater self-regulation). With regard to the relationships between the questionnaire measures, it was hypothesised that greater confidence in difficult driving situations would be associated with higher self-ratings of abilities, greater driving space, greater driving exposure, less avoidance of difficult driving situations, and fewer previous crashes or traffic violations. It was also expected that greater avoidance of difficult driving situations (greater self-regulation) would be associated with lower self-ratings of abilities, lower driving space, lower driving exposure, a greater number of previous crashes and traffic violations, fewer barriers to self-regulation and greater regulatory self-efficacy.

9.2 Analyses

Descriptive statistics for the questionnaire measures are provided, followed by an analysis of the relationships shared by these measures with age, gender, and each other. These relationships were all assessed using Pearson's Product Moment Correlation coefficients, except for the analyses of gender differences, and differences according to previous crash involvement and traffic violations, for which independent samples t-tests were performed. For all analyses, a conservative alpha level of .01 was used rather than the conventional .05, in order to control for multiple comparisons. As noted previously, this conservative alpha level was chosen ahead of using the Bonferroni method of correcting for multiple comparisons because the former allows for a consistent alpha level across the entire thesis rather than a different one for each set of analyses, and also because it has been argued that the Bonferroni method is too conservative when the number of comparisons gets too large (Jaccard & Wan, 1996). The size of correlations and *t*-test differences was also evaluated according to Cohen's (1992) effect size classifications. According to this system of classification, correlations of between .1 and .3 are "small" (accounting for between 1 and 9% of the variance), those between .3 and .5 are "medium-sized"(between 9 and 25% of the variance) and those over .5 are "large"(over 25% of the variance). For *t*-tests, effect sizes (*d*) between 0.2 and 0.5 are regarded as small, those between 0.5 and 0.8 are medium-sized, and those over 0.8 are large (Cohen, 1992).

9.3 Results

9.3.1 Descriptive Statistics for the Driver Mobility Questionnaire

9.3.1.1 Current Driving

Of the 104 drivers surveyed, all but six preferred to meet their transport needs by driving themselves (Question 1). Four expressed a preference for travelling by taxi or public transportation and the remaining two participants preferred having someone else drive them in a private vehicle. Just over 60% of drivers reported always wearing glasses when they drove (Q2).

When asked to compare their usual driving speed with that of other traffic (Q3), 92 (88.5%) of the participants claimed that they drove at "about the same" speed as other drivers. The other 12 (11.5%) participants admitted that they generally drove more slowly than other traffic.

Only six of the participants admitted that it had been suggested to them that they cease or restrict driving (Q4). It is interesting that this accounts for only half of the participants who were referred for a driving assessment, mostly by medical practitioners.

9.3.1.2 Self-Ratings of Abilities

When asked to rate their own driving ability (Q5), only one participant claimed that they were below average ("fair"). Forty participants (38.5%) judged themselves to be average drivers, 60 (57.7%) said they were "good" drivers, and the remaining three claimed that they were "excellent". This suggests a generally positive self-assessment of driving ability among the participants.

The results for the question about self-ratings of vision (allowing for correction by glasses) (Q6) were similar to those for self-ratings of driving ability, with only three admitting their vision was below average ("fair"). Forty participants (38.5%) claimed their vision was average, 47 (45.2%) claimed that theirs was "good", and the other 14 (13.5%) rated their vision as "excellent".

The pattern of results for self-ratings of the ability to perform two tasks simultaneously (Q7) was also similar to that for the previous two questions, except that more participants rated their dual task ability as below average (10 participants or 9.6%) than rated it as "excellent" (six participants or 5.8%). Again, almost all participants judged themselves to be either average (43 participants or 41.3%) or "good" (45 participants or 43.3%).

9.3.1.3 Driving Exposure

The amount of driving done by the study participants was assessed in three ways. The participants were asked to state the number of days per week they typically drove (Q9), the number of trips they typically took per week (Q10), and the number of kilometres they drove per week (Q11). The number of days per week that the participants typically drove is displayed in Table 9.1. There was considerable variation in the number of days driven per week but few participants drove less than three days per week (6 participants or 5.8%). The most frequent response was seven days per week.

Table 9.1
Days driven per week (N = 104)

Days driven per week	Number of participants	Percentage of participants
1	1	1.0
2	5	4.8
3	10	9.6
4	14	13.5
5	25	24.0
6	17	16.3
7	32	30.8
Total	104	100.0

The number of trips typically taken per week by the participants (Q10) ranged from two to 30, with a mean of 8.6 (*SD* = 5.4). Fifty five percent of participants took seven trips per week or less (an average of one per day or less), while only 13.5% took more than 14 trips per week (an average of two per day or more). In terms of kilometres driven (Q11), the amount of driving per week ranged from 15 to 360 km, with a median of 110 km.

The majority of the participants (*n* = 61, 58.7%) reported that they had reduced the amount of driving they did in the last ten years, while the remaining 43 (41.3%) had not (Q12). When asked to provide reasons for their reported driving reduction, 55 of the 61 participants attributed it to a reduction in the need to drive. The reduction in driving, according to this attribution, was due to changes in lifestyle (probably retirement in many cases) meaning that less driving was necessary than previously. Only three participants reduced their driving to save money and one did it because of a decline in vision.

9.3.1.4 Driving Confidence

Participants were asked to rate their confidence in nine difficult driving situations, using a five point scale with five points for "completely confident" and one point for "not confident at all" (Q13-21). As stated in section 6.2.2.1, an overall driving confidence variable was calculated with a possible range from nine (not confident at all in any difficult driving situation) to 45 (completely confident in all situations). The overall confidence scores for the 104 participants ranged from 19 to 45, with a mean of 33.1 (*SD* = 6.5).

With regard to each individual driving situation, a summary of participants' confidence ratings is provided in Figure 9.1 (a table of data is provided in Appendix 9, Table 1), which shows that the situation in which participants were *most* confident was driving alone (Figure 9.1, b), while the situations in which there was the *least* confidence were parallel parking and driving at night in the rain (Figure 9.1, c and i). The most common response for six of the nine categories was "reasonably confident" and participants were more likely to report being "very" or "completely" confident than they were to report being "not confident at all" or "not very confident".

9.3.1.5 Crashes and Traffic Violations

Participants were asked to report the number of crashes they had been involved in as a driver in the previous five years (Q22). Their responses are summarised in Table 9.2, which shows that three quarters of the participants had not been involved in a crash in the previous five years. Only seven percent had had more than one crash in the five year period.

Table 9.2
Number of crashes in the previous five years (N = 104)

Number of crashes	Number of participants	Percentage of participants
0	79	76.0
1	18	17.3
2	5	4.8
3	1	1.0
4	1	1.0
Total	104	100.0

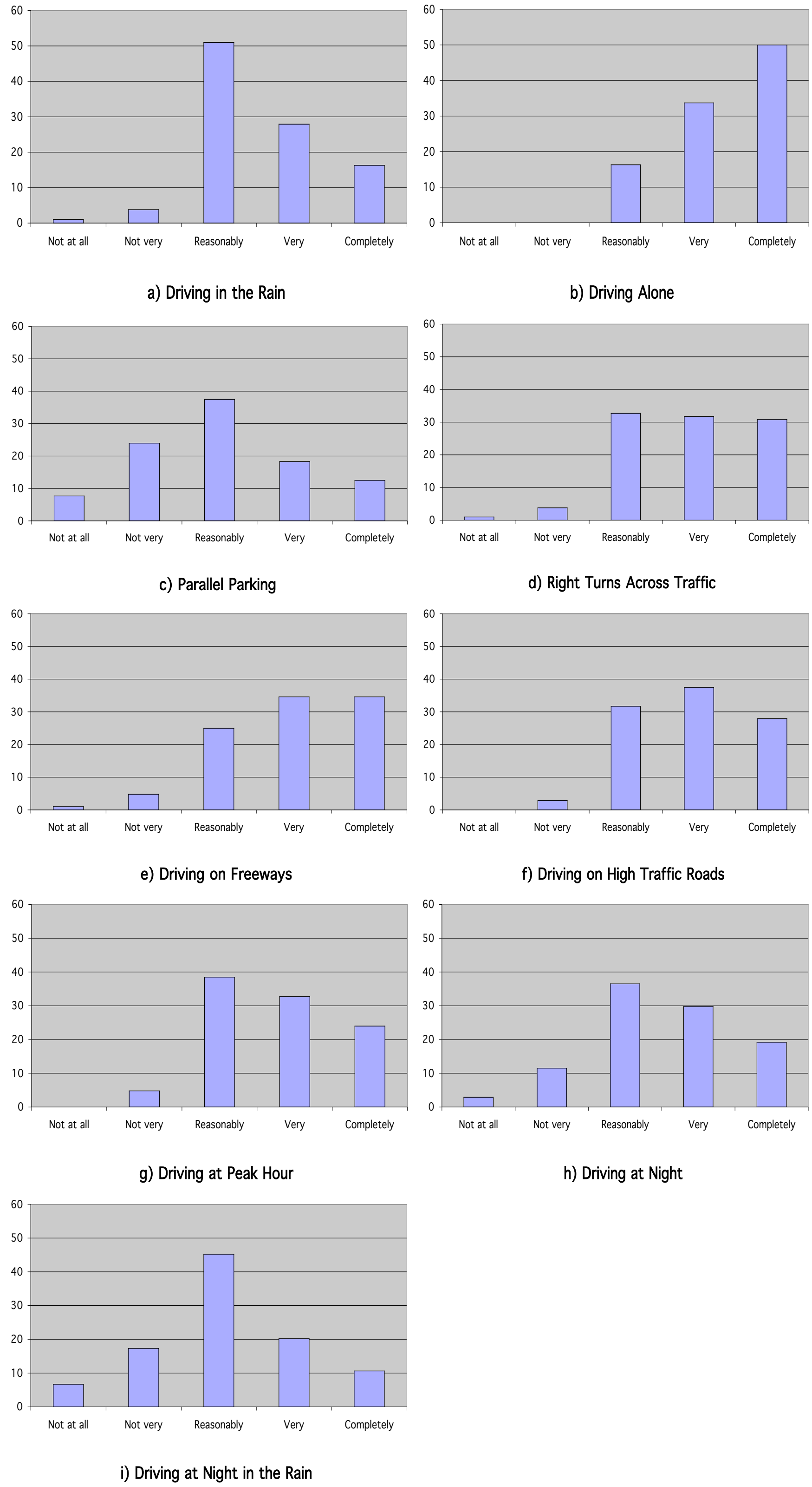

Figure 9.1. Confidence in difficult driving situations, percentages

Participants also reported the number of police-reported crashes in which they had been involved in the same time period (Q23). Ninety five of the drivers (91.3%)

had not been in a police-reported crash in the previous five years, eight (7.7%) had been in one, and only one driver had been in two, giving a total of 10 police-reported crashes for the 104 participants. An examination of TARS crash records (providing details of all police-reported crashes in South Australia) was undertaken to check the accuracy of the participants' self-reports. Five of the 104 participants declined to provide their licence number, reducing the sample for this analysis to 99. Of these 99 participants, 13 had been involved in a single police-reported crash, three had been in two, and one had been in three, giving a total of 22 crashes. The self-reports for these 99 drivers indicated a total of 30 crashes but only ten that were reported to the police. Therefore, self-reports yielded a higher number of crashes but fewer police-reported crashes than indicated by official records.

Participants were also asked whether they had been pulled over by the police when driving in the previous five years (Q24). Only seven participants reported that this had occurred and none of them reported it happening more than once.

The number of traffic violations (e.g. speeding) in the previous five years was also ascertained for the participants through self-report (Q25). Eighty five participants (81.7%) reported no traffic violations in the previous five years, 14 (13.5%) reported one, four (3.8%) reported two and one driver reported three. Therefore, traffic violations occurred slightly less often than crashes (refer to Table 9.2).

9.3.1.6 Driving Space

The geographical area in which the participants drove (their "driving space") was assessed by asking the participants if, in the previous year, they drove in their local neighbourhood (Q26), if they drove beyond their local neighbourhood (Q27), if they drove in an unfamiliar part of the city (Q28), if they drove beyond the metropolitan area (Q29), and if they drove outside the state (Q30). As stated in section 6.2.2.1, a point was awarded for each of these questions if the answer was “yes”, to give a total driving space score out of five. The mean score for driving space was 4.0 (SD = 0.9), demonstrating little restriction of the geographical area in which the participants drove.

It is also instructive to look at the responses to the individual questions to give a more detailed picture of the participants’ driving behaviour. The responses to each of the five questions are summarised in Table 9.3, which shows that all participants had driven in their local neighbourhood and nearly all had driven beyond it. Driving outside the metropolitan area and driving in an unfamiliar part of the city were both done by approximately 85% of participants, while approximately two thirds had also driven outside the state. Again, this suggests that the sample of drivers was very mobile.

Table 9.3
Responses to the individual “driving space” questions concerning areas driven in during the previous year (N = 104)

Area	Yes (%)	No (%)
Local neighbourhood	100.0	0.0
Beyond the local neighbourhood	99.0	1.0
Unfamiliar part of the city	84.6	15.4
Outside the metropolitan area	86.5	13.5
Outside the state	68.3	31.7

9.3.1.7 Driving Avoidance

Avoidance of difficult driving situations was scored on a five point scale (1 = ‘never’ to 5 = ‘always’) for each driving situation (Q31-39). Again, an overall score was calculated with a possible range from nine (never avoid any difficult driving situations) to 45 (always avoid all difficult situations). The range of scores for this measure of avoidance was nine to 32, with a mean of 13.9 (SD = 5.6).

Figure 9.2 shows the levels of avoidance of each of the difficult driving situations (a table of data is provided in Appendix 9, Table 2). It can be seen that there was a tendency among participants to report never avoiding these difficult situations. Only parallel parking was avoided at least rarely by over half of the participants (refer to Figure 9.2, c). Along with parallel parking, the most avoided difficult driving situation was driving at night in the rain (refer to Figure 9.2, i). The least avoided driving situation was driving alone (refer to Figure 9.2, b).

9.3.1.8 Perceived Barriers to Self-Restriction of Driving

A number of questions addressed the possibility that certain factors would act as barriers stopping participants from self-regulating their driving behaviour. These included the participants' lifestyles (Q40), whether they were relied upon by others to drive (Q41), the availability of public transport (Q42), willingness to use public transport (Q43), the availability of family or friends to provide transport when needed (Q44), and whether they felt comfortable asking family or friends to provide transport (Q45). For each type of barrier, the participants had to rate their level of agreement with a statement that the barrier made it difficult to change when and where they drive. As stated in section 6.2.2.1, this was done on a four point scale, with one point for "strongly disagree" to four points for "strongly agree". A total score for barriers to self-restriction was then calculated, ranging from a low of six to a high of 24, with higher scores indicating greater barriers to changing driving behaviour. The mean for this variable was 14.3 (SD = 4.3). A summary of the responses to each question is provided in Table 9.4, which shows that the greatest barrier to self-regulation among the participants was lifestyle. That is, many participants were used to a certain lifestyle that entailed a certain amount of driving, and maintenance of this lifestyle required maintenance of their driving behaviour. The lack of availability of others to provide transport and the participants' lack of willingness to ask others were the next greatest barriers to self-regulation.

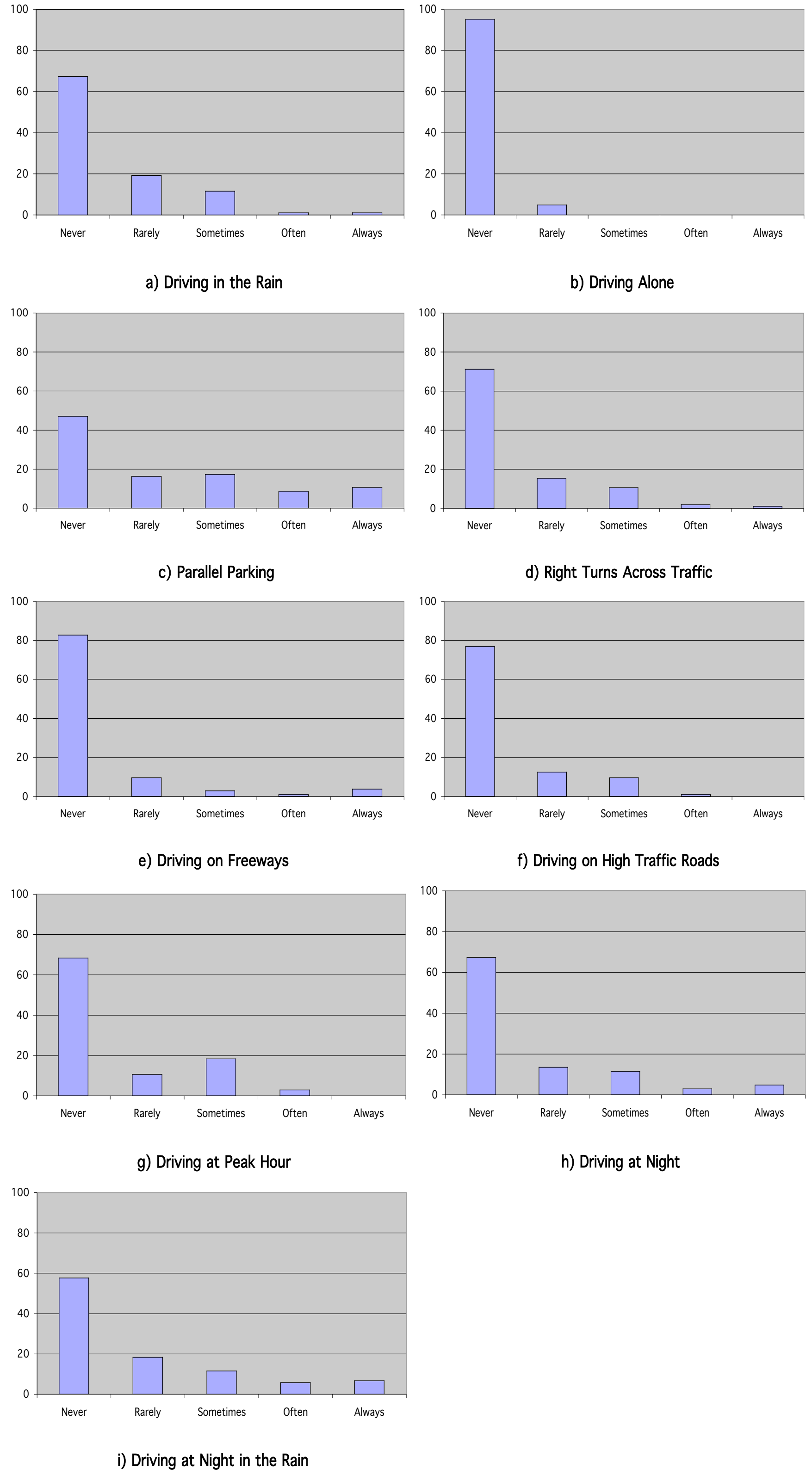

Figure 9.2. Avoidance of difficult driving situations, percentages

Table 9.4
Perceived barriers to self-regulation, percentage of participants (N = 104)

Type of barrier	Strongly disagree (%)	Disagree (%)	Agree (%)	Strongly agree (%)
Lifestyle	6.7	25.0	29.8	38.5
Relied on to drive others	23.1	38.5	23.1	15.4
No public transport	32.7	40.4	14.4	12.5
Don't like public transport	26.9	46.2	12.5	14.4
Family or friends unavailable	24.0	33.7	24.0	18.3
Would not ask family or friends	20.2	35.6	24.0	20.2

9.3.1.9 Regulatory Self-Efficacy

Another way of assessing older drivers' abilities to change their driving behaviour is to ask them how easy or difficult it would be to avoid specific difficult driving situations (Q46-53). For each driving situation, participants had to say whether avoiding it would be "very hard" (one point), "somewhat hard" (two points) or "not hard at all" (three points). As stated in section 6.2.2.1, scores for these questions were then summed to yield a score for regulatory self-efficacy ranging from eight (no ability to self-regulate) to 24 (self-regulation not hard at all). The mean for this variable was 17.4 (*SD* = 4.4). A summary of responses to each item on the scale is provided in Table 9.5. The hardest situations to avoid, according to the participants, were driving alone (the situation most often designated as very hard to avoid) and high traffic roads (the situation least often designated as not hard at all to avoid). The situations easiest to avoid were parallel parking and peak hour.

Table 9.5
Self-regulatory self efficacy, percentage of participants (N = 104)

Driving situation to avoid	Very hard to avoid (%)	Somewhat hard to avoid (%)	Not at all hard to avoid (%)
Rain	31.7	27.9	40.4
Alone	45.2	25.0	29.8
Parallel parking	13.5	20.2	66.3
Right turns	26.9	26.9	46.2
Freeways	26.0	30.8	43.3
High traffic roads	29.8	43.3	26.9
Peak hour	13.5	32.7	53.8
Night	25.0	31.7	43.3

9.3.1.10 Summary

The results from the Driver Mobility Questionnaire indicate that the sample under investigation was very mobile and confident. Very few drivers preferred someone else to drive, drove slower than other traffic, had been given suggestions to restrict their driving, or rated their abilities as being below average. There was great variation in the amount of driving done but few drivers had restricted their driving space (the geographical area in which they drove). The majority of drivers had reduced their driving in the previous ten years, mostly due to a reduced need to drive. There were high levels of confidence in, and low levels of avoidance of, difficult driving situations, with the most commonly avoided situations being parallel parking and driving at night in the rain. Around one quarter of drivers reported a crash in the last five years (although reference to official crash data suggested that participants may have under-reported their crash involvement) and slightly fewer reported having been charged with a traffic violation. The greatest barriers to self-restriction of driving were lifestyle and not having other drivers to rely on, while the driving situations thought to be most difficult to avoid, if required, were driving alone and on high traffic roads.

9.3.2 Relationships Between Questionnaire Measures, Age and Gender

This section examines the correlations between the various questionnaire measures and age, and also examines gender differences using *t*-tests. Although it was expected that self-ratings of abilities, driving exposure, and driving space would decrease with age, age was not significantly correlated with any of these variables (refer to Table 9.6).

Table 9.6

Correlations between age and driving-related variables (N = 104)

Driving variable	Correlation with age
Self-ratings	
Self-ratings of driving ability	-.18
Self-ratings of vision	-.05
Self-ratings of dual task ability	-.21
Driving exposure	
Days driven per week	-.20
Trips taken per week	-.18
Kilometres driven per week	-.20
Driving Space	
Total driving space	-.09

* $p < .01$, ** $p < .001$

With regard to gender, the only variable in Table 9.6 for which there was a significant gender difference was total driving space. As expected, males were found to have greater driving space (M = 4.3, SD = 0.7) than females (M = 3.9, *SD* = 0.9) ($t_{(102)}$ = 2.84, $p = .005$). This difference equates to a medium effect size ($d = 0.55$).

It had been expected that increased age would be associated with lower confidence in difficult driving situations but it can be seen in Table 9.7 that the only individual confidence measures that were significantly related to age, both with medium sized correlations, were confidence driving at night and confidence driving at night in the rain. In each case, lower confidence was associated with increased age. With regard to overall confidence, there was a trend towards lower confidence with age but it was not statistically significant ($p = .040$).

Table 9.7

Correlations between age and driving confidence in difficult situations (N = 104)

Confidence measure	Correlation with age
In the rain	-.17
When alone	-.00
Parallel parking	-.06
Right turns	.01
Freeways	-.15
High traffic roads	-.12
Peak hour	-.17
At night	-.36**
At night in the rain	-.34**
Overall	-.20

* $p < .01$, ** $p < .001$

There was little difference between males and females in terms of confidence in difficult driving situations. The only driving confidence score for which there was a trend towards a difference between the genders was that for confidence when parallel parking (M_{males} = 3.4, SD = 1.0, $M_{females}$ = 2.8, SD = 1.1). This difference was not significant ($t_{(102)}$ = 2.52, p = .013) but reflected a medium effect size (d = 0.50). Contrary to expectations, overall driving confidence scores were not significantly different between males and females.

The correlations between age and driving avoidance measures are shown in Table 9.8. Similar to the findings for driving confidence, the strongest associations with age among the driving avoidance measures were for driving at night and driving at night in the rain, both with medium sized correlations. Overall avoidance was also significantly correlated with age. In all cases, as expected, increased age was associated with increased avoidance.

Table 9.8
Correlations between age and avoidance of difficult driving situations (N = 104)

Avoidance measure	Correlation with age
In the rain	.23
When alone	-.02
Parallel parking	.04
Right turns	-.05
Freeways	.05
High traffic roads	.25
Peak hour	.13
At night	.38**
At night in the rain	.39**
Overall	.26*

* $p < .01$, ** $p < .001$

Females were found to show significantly greater avoidance of parallel parking (M_{males} = 1.5, SD = 0.8; $M_{females}$ = 2.6, SD = 1.5; $t_{(100.5)}$ = 4.81, p = *.000*, d = 0.78) and freeway driving (M_{males} = 1.1, SD = 0.3; $M_{females}$ = 1.5, SD = 1.1; $t_{(76.4)}$ = 2.92, p = .005, d = 0.47). With regard to overall avoidance, there was a non-significant trend towards females avoiding more difficult driving situations than men (M_{males} = 12.4, SD = 4.5; $M_{females}$ = 14.9, SD = 6.0; $t_{(102)}$ = 2.20, p = .030), corresponding to a small to medium effect size of 0.44. That there was evidence of females avoiding difficult driving situations more than males was consistent with expectations.

9.3.3 Relationships Between Questionnaire Measures

This section explores the correlations between the various measures included in the questionnaire. It focuses on the relationships of both driving confidence and driving avoidance with self-ratings of abilities, driving exposure, driving space, and previous crashes and traffic violations. The relationships between driving confidence and driving avoidance are also examined, as are those between driving avoidance, and perceived barriers to self-regulation and total regulatory self-efficacy.

9.3.3.1 Driving Confidence

Correlations were used to assess the relationship between overall confidence in difficult driving situations (the sum of confidence ratings for nine different situations) and other driving attitudes and behaviours. The correlations with self-ratings of abilities, driving exposure variables, and driving space are shown in Table 9.9. As expected, participants' self-ratings of abilities (driving, visual, dual task) were significantly correlated with their overall driving confidence, with correlations falling in the medium to large range. Greater self-ratings were associated with greater confidence. Neither driving exposure nor driving space was significantly correlated with overall driving confidence, indicating that low driving confidence did not limit the amount of driving participants did or the geographical area over which participants drove.

Table 9.9

Correlations between overall driving confidence and various driving attitudes and behaviours (N = 104)

Driving Variable	Correlation with overall driving confidence
Self-ratings	
Self-ratings of driving ability	.45**
Self-ratings of vision	.29*
Self-ratings of dual task ability	.59**
Driving exposure	
Days driven per week	.16
Trips taken per week	.11
Kilometres driven per week	.21
Driving Space	
Total driving space	.09

* $p < .01$, ** $p < .001$

Driving confidence was also expected to be related to driving avoidance, with more confident drivers reporting less avoidance and vice versa, resulting in a significant negative correlation between the two. As the confidence and avoidance questions were based on the same set of driving situations, correlations were calculated between the confidence and avoidance responses for each specific driving situation, as well as between overall confidence and overall avoidance. As seen in Table 9.10, all correlations were significant, with almost all being medium to large in size. This suggests that a lack of confidence in a specific situation was associated with avoidance of that situation. The strongest correlations between confidence and avoidance were for parallel parking, driving at night and driving at night in the rain, while the smallest correlation was for driving alone. Referring back to sections 9.3.1.4 and 9.3.1.7, it can be seen that the strongest correlations between confidence and avoidance were for situations associated with lower confidence and higher avoidance, (parallel parking, driving at night and driving at night in the rain), while the smallest correlation between confidence and avoidance was for the situation (driving alone) characterised by high confidence and low avoidance.

Table 9.10
Correlations between confidence and avoidance scores for a variety of difficult driving situations (N = 104)

Driving situation	Correlation between confidence & avoidance
In the rain	-.44**
When alone	-.28*
Parallel parking	-.67**
Right turns	-.57**
Freeways	-.64**
High traffic roads	-.43**
Peak hour	-.52**
At night	-.67**
At night in the rain	-.66**
Overall	-.67**

* $p < .01$, ** $p < .001$

The possibility that previous crashes or traffic violations were associated with lower overall confidence in difficult driving situations was assessed with independent samples *t*-tests. The results of these analyses are summarised in Table 9.11, which shows that overall driving confidence did not differ according to prior crash involvement or traffic violation.

Table 9.11
The differences in overall driving confidence between those who had been involved in crashes or been charged with traffic violations and those who had not (N = 104)

Type of crash or violation	Mean confidence (*SD*)	*n*	*t* score
Self-reports			
Had any crash	32.0 (6.9)	25	
No crashes	33.4 (6.4)	79	0.92
Had a police-reported crash	29.2 (7.6)	9	
No police-reported crashes	33.4 (6.3)	95	1.86
Pulled over by the police	29.9 (7.5)	7	
Not pulled over	33.3 (6.4)	97	1.34
At least one traffic violation	33.7 (6.8)	19	
No traffic violations	32.9 (6.5)	85	0.47
Official records ($n = 99$)			
Had a police-reported crash	33.7 (7.2)	17	
No police-reported crash	32.9 (6.6)	82	0.41

* $p < .01$, ** $p < .001$

9.3.3.2 Driving Avoidance

Correlations were used to assess the relationships between the avoidance of difficult driving situations (measured by the sum of avoidance ratings for nine different situations) and self-ratings of abilities, driving exposure, and driving space (refer to Table 9.12). It can be seen that greater avoidance of difficult driving situations was related to lower self-ratings of driving ability and dual task ability. Avoidance of difficult driving situations also correlated significantly with reduced driving space. As with confidence scores (refer to Table 9.9), driving avoidance was more strongly related to self-ratings of dual task ability (a medium sized correlation) than to the other variables (all small correlations).

Table 9.12
Correlations between overall driving avoidance and various driving attitudes and behaviour variables (N = 104)

Driving Variable	Correlation with overall driving avoidance
Self-ratings	
Self-ratings of driving ability	-.29*
Self-ratings of vision	-.06
Self-ratings of dual task ability	-.42**
Driving exposure	
Days driven per week	-.08
Trips taken per week	-.12
Kilometres driven per week	-.22
Driving Space	
Total driving space	-.26*

* $p < .01$, ** $p < .001$

The possibility that previous involvement in crashes or being charged with traffic violations was related to driving avoidance was tested by a series of independent samples *t* tests comparing the overall avoidance scores (refer to section 9.3.1.7) for those participants who had crashed or committed violations with scores for those participants who had not. These results are summarised in Table 9.13. As was the case for driving confidence (refer to Table 9.11), there were no differences in driving avoidance according to previous involvement in crashes or having been charged with traffic violations.

Table 9.13

The differences in overall driving avoidance between those who had been involved in crashes or been charged with traffic violations and those who had not (N = 104)

Type of crash or violation	Mean avoidance (*SD*)	*n*	*t* score
Self-reports			
Had any crash	14.1 (6.3)	25	
No crashes	13.9 (5.4)	79	0.15
Had a police-reported crash	17.1 (8.0)	9	
No police reported crashes	13.6 (5.2)	95	1.28
Pulled over by the police	16.1 (7.2)	7	
Not pulled over	13.8 (5.4)	97	1.09
At least one traffic violation	12.7 (5.4)	19	
No traffic violations	14.2 (5.6)	85	1.04
Official records (n = 99)			
Had a police-reported crash	13.7 (6.0)	17	
No police reported crashes	14.2 (5.6)	82	0.39

* $p < .01$, ** $p < .001$

Finally, the correlation between overall avoidance of difficult driving situations and total perceived barriers to self-regulation was not found to be significant (r = -.09, p = .347). This finding was contrary to expectations that lower driving avoidance would be associated with greater perceived barriers to self-regulation. However, the finding of a significant correlation between overall avoidance and regulatory self-efficacy, or the ease of organising one's life so that difficult driving situations may be avoided, (r = .28, p = .004) was consistent with expectations.

9.4 Discussion

The Driver Mobility Questionnaire asked participants to provide details about their current driving status, the amount of driving they did, their self-ratings of different abilities (driving, vision, dual tasks), any reductions in the last ten years in the amount of driving they did, whether anyone had suggested they restrict or cease their driving, their confidence in difficult driving situations, crashes that they were involved in and traffic violations that they were charged with during the previous five years, their driving space (geographical extent of their driving), their avoidance of difficult driving situations, any barriers they encountered to restriction of driving, and the ease with which they could avoid difficult driving situations if they wished. Gender differences and relationships with age were investigated for these variables, and the relationships between the variables were also examined.

9.4.1 Current Driving Practices and Attitudes

The examination of current driving attitudes and behaviour revealed a clear desire for independent mobility, with all but six drivers preferring to drive themselves rather than using public transportation or being driven by someone else. This obvious preference for driving is consistent with findings that older adults remain dependent on car travel for their transportation needs (Jette & Branch, 1992). The majority of drivers also drove five days per week or more, while very few reported having restricted driving space, consistent with a previous study in the USA by Owsley et al. (1999). Nearly 70% of drivers in the present study reported driving outside the state in the previous year, indicating a high degree of mobility. However, high variability of driving behaviour was evident in the findings that trips taken by car per week ranged from two to 30, while kilometres driven per week ranged from 15 to 360. Therefore, older adults almost universally prefer independent mobility but there is considerable variability in the extent to which they exercise this mobility.

The majority of drivers reported reducing their driving in the last ten years and almost all of these drivers reported doing so because they had less need to drive. It could be that this reduced need to drive was mainly due to retirement, which has previously been linked to reduced driving among older adults (e.g. Raitanen et al., 2003). It is also notable that this explanation for reduced driving was almost universally given rather than one couched in terms of declines in functional abilities that necessitated lower levels of driving. However, Kelly (1999) cautioned that financial reasons may be given by older adults for driving cessation rather than admitting that cessation was brought about by declining abilities. It is possible that this bias in responses when older adults are asked about cessation also occurs when they are asked about reductions in driving. Furthermore, only six participants admitted that it had been suggested to them that they cease or restrict driving. This is less than half the number who were referred for a driving assessment. It is possible that some of the drivers who had been referred for an assessment omitted to mention that it had been suggested to them that they cease or restrict their driving, or it may be that referral for assessment in some cases was not specifically associated with a recommendation for restriction or cessation of driving but merely with a recommendation that driving ability be assessed.

The majority of drivers claimed that they had above average ("good" or "excellent") driving ability and vision, with very few admitting to below average abilities (one for driving ability, three for vision). The finding of high self-ratings of vision among older drivers is consistent with a study by Kline et al. (1992) who found that over 90% of drivers aged 60 to 79, and over 70% of those aged 80 or more, reported their vision to be "good" or "excellent". Similarly, a recent survey by Charlton et al. (2003) found that 76% of drivers aged over 55 described their vision at night as "good" or "excellent". High self-ratings for driving ability have also been reported previously in a study by Owsley et al. (1999) in which 86% of older drivers reported being above average ("good" or "excellent") drivers. As few participants in the present study claimed to be below average drivers, it would be expected that few would report feeling it necessary to drive more slowly than other traffic and, indeed, only 12% claimed to do so. For self-ratings of dual task ability, a slight majority of participants reported being either "average" or "fair" rather than "good" or "excellent" (53 versus 51) but the results still indicated that few drivers thought that there were any deficits in their dual task ability (none said "poor", 10 said "fair").

Nearly a quarter of the sample of older drivers reported having been in a crash in the past five years, with ten of these 35 crashes having been reported to the police. An analysis of the official records (the TARS database) revealed that, for the 99 participants who provided their licence number and whose self-reports indicated 30 crashes in the previous five years, there were a total of 22 crashes reported to the police. Therefore, overall self-reported crash numbers were higher than those in the official records, as previously reported by Marottoli et al. (1997) and Fildes et al. (1994), which is likely to be due to self-reports including crashes not severe enough to be reported to the police and entered into official records. However, participants under-reported crashes that were reported to the police (self-reports indicating 10 police-reported crashes rather than 22). It could be that some drivers forgot that their crashes were reported to the police but, of the 17 drivers whose crashes were included in the TARS database, there were six whose number of crashes in the official database exceeded the number of crashes they claimed to have had (i.e. self-reports), including non-police reported crashes. This indicates that some crashes must have been omitted from participants' self-reports. These findings vindicate the decision to obtain both self-reported *and* official crash data.

According to the official South Australian police crash statistics for a five year period from 1994 to 1998, examined in detail in Chapter 2, the number of crashes per 100 licensed drivers for different age groups was 21.5 for those aged 55 to 64, 20.9 for those aged 65 to 74, 18.7 for those aged 75 to 84 and 19.6 for those aged over 84 (refer to section 2.3.1.3). A total of 22 police-reported crashes among the 99 study participants equates to a rate of 22.2%. This comparison suggests that, with regard to crash involvement, the drivers in the sample were representative of the overall older driver population in South Australia.

The greatest perceived barrier to self-regulation was maintenance of lifestyle, reported by nearly 70% of participants, followed by the unavailability of family and friends to provide transport when needed (42%) or the unwillingness to ask them for help with transportation (44%). A quarter of participants claimed that public transportation was unavailable to them. For comparison, a study in the USA by Stalvey and Owsley (2000) found that inadequate public transportation was reported by three quarters of respondents to be a barrier to self-regulation, followed by the unavailability of friends or family (57%) and maintenance of lifestyle (54%). In both this and Stalvey and Owsley's study, being relied on by others for transport was reported by just over 35% of drivers. It appears that the two sets of responses are broadly comparable, except that the provision of public transportation in Adelaide, South Australia was viewed more favourably than that in the region of the USA where Stalvey and Owsley conducted their study.

When asked about the ease or difficulty of avoiding specific difficult driving situations if it was their wish to do so, driving alone and high traffic roads were reported to be the most difficult to avoid, while parallel parking and peak hour were reported to be the easiest to avoid. The need to drive alone fits with the desire for independent mobility, while the difficulty of avoiding high traffic roads is likely to be due to the fact that the study participants live in the metropolitan area, a situation in which it is difficult to travel beyond one's immediate neighbourhood without encountering an arterial road featuring heavy traffic. All participants reported driving beyond their immediate neighbourhood and so avoidance of high traffic roads would have been difficult. The relative ease of avoiding parallel parking would be due to drivers being able to find parking spaces that did not require that manoeuvre. Avoidance of peak hour, on the other hand, could be related to retirement and the ability to choose when driving is done (Eberhard, 1996).

The results for the questions about confidence in, and avoidance of, difficult driving situations were consistent with each other, with confidence scores generally at the higher end of the scale, while avoidance scores were generally at the lower end. This suggests a confident sample of drivers who did not often find it necessary to avoid difficult driving situations. Also consistent were the findings of low confidence and high avoidance for parallel parking and driving at night in the rain, while there was high confidence and low avoidance reported for driving alone. The finding that driving alone was the least avoided difficult situation and was not viewed as very difficult (high level of confidence) is consistent with previous studies examining this set of difficult driving situations (Ball et al., 1998; Owsley et al., 1999; Stalvey & Owsley, 2000). The lack of avoidance of driving alone also reflects the difficulty of doing so, as expressed by the participants, while the higher avoidance of parallel parking would be related to the reported ease of avoiding it.

9.4.2 Relationships With Age and Gender

Age was not found to be significantly related to any of the self-rated variables (driving ability, vision, dual task ability). This was contrary to expectations that, with increasing age, older adults would be more likely to perceive declines in such abilities. Furthermore, as increased age was associated with poorer vision and poorer driving performance according to objective measures (see section 8.3.3), this suggests that many older adults may be unaware of declines in these abilities. This suggestion is tested more directly in Chapter 10, when self-ratings of abilities (driving, vision, dual task) are directly compared to the objective measures of those abilities.

In terms of the amount of driving done, age was not associated with self-reported measures of driving exposure (days driven per week, trips taken per week, kilometres driven per week) or driving space (the geographical area in which driving is done). This is inconsistent with previous research, which has reported decreases in driving with age (Lyman et al., 2002; Maycock, 1997; OECD, 2001; Rabbitt et al., 2002; Ryan et al., 1998). The failure to find a relationship between age and driving exposure could be due to inaccuracies in the responses of the participants. In particular, it could be that participants had difficulties accurately estimating the number of kilometres driven per week. The lack of a relationship between age and driving space was also contrary to expectations but may be due to the fact that there were few drivers in the sample who restricted their driving space.

Increased age shared moderate relationships with both lower confidence in, and greater avoidance of, night driving and driving at night in the rain. Also, increased age shared a limited relationship with overall avoidance. A relationship between age and driving avoidance has been reported in previous research (Charlton et al., 2003; Cooper, 1990b; Forrest et al., 1997; Holland & Rabbitt, 1994; Raitanen et al., 2003; Rimmo & Hakamies-Blomqvist, 2002), whereas the relationship between age and confidence has not (Marottoli & Richardson, 1998; Rabbitt et al., 2002). The present study was consistent with the latter findings, in that overall confidence was not lower with increased age, but the present study has also demonstrated that age is associated with reductions in confidence in *specific* driving situations. That is, for the most part, confidence when driving stays intact with increased age but appears to decrease when driving at night and at night in the rain.

In regard to gender, females were found to have a smaller driving space than males, and to be more likely to avoid parallel parking and driving on freeways. Although these gender differences were minor, they were consistent with previous findings that females practise greater self-regulation of driving than males (Burns, 1999; Gallo et al., 1999; Raitanen et al., 2003; Rimmo & Hakamies-Blomqvist, 2002). It will be interesting to see if these patterns remain in the future, given that the driving behaviour of females more closely matches that of males in younger cohorts (Eberhard, 1996; Hakamies-Blomqvist, 1996; Laapotti, 1991; Weinand, 1996).

9.4.3 Relationships Between Questionnaire Measures

Overall driving confidence was related to each of the self-ratings of abilities, with the strongest relationship being with perceived dual task ability. Relationships between self-rated abilities and driving confidence have been reported before (Marottoli & Richardson, 1998; Parker, McDonald, Sutcliffe, & Rabbitt, 2001) but the present study is the first to examine perceived dual task ability. It could be that difficulties performing simultaneous tasks when driving are detected by older drivers prior to any problems with driving overall, resulting in a stronger relationship between confidence and perceived dual task ability than between confidence and perceived driving ability.

There were no significant relationships between overall confidence and driving exposure (the amount of driving done) or driving space (the geographical area in which driving was done). This was contrary to expectations, given that relationships between confidence and the amount of driving done have been found in other studies (Marottoli & Richardson, 1998; Parker et al., 2001; Rabbitt et al., 2002). As noted earlier, the failure to find significant correlations with driving exposure and driving space could be due to inaccuracies in the participants' estimates of driving exposure and the rarity of restriction of driving space among the study participants, respectively.

The failure to find differences in confidence according to previous crash involvement or traffic violations is consistent with active older drivers disregarding such incidents when assessing their capabilities, possibly regarding them as being due to external or unstable factors, such as errors by other drivers or bad luck. Age differences in attribution for crashes and violations would be an interesting area for future research. It is also possible that the confidence of crash-involved drivers was once higher prior to the crashes. Marottoli et al. (1998) also failed to find a relationship between confidence and previous crashes or violations.

With the exception of driving alone, there were moderate to large relationships (r = -.43 to -.67) between confidence and avoidance scores for the various difficult driving situations. This is consistent with drivers avoiding the situations in which they lose self-confidence or, alternatively, with confidence in situations declining if those situations are avoided. The lower, but still significant, correlation (-.28) between confidence when driving alone and avoidance of driving alone may be the result of very few drivers reporting ever avoiding it. This lack of avoidance of driving alone, as noted earlier, could have been partly the result of the difficulty, as expressed by the participants, of avoiding this situation.

Conversely, the strong correlation (-.67) between confidence when parallel parking and avoidance of parallel parking could be related to the ease, as expressed by the participants, of avoiding parallel parking if it was felt necessary. That is, drivers did not find it difficult to avoid parallel parking and so, if they lacked confidence in performing that manoeuvre, they were able to avoid it. In this way, the ease of avoiding a difficult driving situation, if a person wishes to, could have considerable bearing on whether avoidance of that situation is related to decreased confidence in it. The hardest situations to avoid, according to the participants, were driving alone and high traffic roads, while the easiest to avoid were parallel parking and peak hour. The relationship between low *overall* confidence in, and high *overall* avoidance of, difficult driving situations is consistent with the findings of Charlton et al. (2003).

Overall avoidance of difficult driving situations (a measure of self-regulation) was found to be associated with lower self-ratings of driving and dual task ability but not self-ratings of vision. Therefore, it is possible that detection of declining vision lowers confidence when driving in difficult situations but does not prompt avoidance of them. However, as vision was mostly rated by participants at the higher end of the scale, it may be that it is only when vision is believed to be below average or poor that avoidance of driving occurs among older drivers. Charlton et al. (2003) did find that those with lower self-rated vision were more likely to report avoidance of driving, although that study used avoidance of any situation as the outcome variable rather than a variable summing frequencies of avoidance of a number of situations.

Overall avoidance of difficult driving situations was also related to a smaller driving space (a smaller geographical area in which driving was done), suggesting that those practising self-regulation tend to experience some restriction of mobility. It could also be that those who reduce the geographical area in which they drive also decide to accompany this reduction in driving with avoidance of difficult driving situations. For example, someone who does not drive beyond the metropolitan area may find that they can also avoid driving on freeways. In contrast to driving space, there were no significant relationships between avoidance and driving exposure. The latter finding may provide an indication that mobility is not greatly restricted by self-regulation or, again, it could be due to inaccuracies in participants' estimates of the amount of driving they did.

Finally, avoidance of difficult driving situations was not related to self-reported crash or violation history, consistent with the finding for driving confidence. While Ball et al. (1998) found self-regulation to be greater among those who had previously crashed, Daigeneault et al. (2002a) did not. As noted earlier for confidence, it could be that the avoidance levels of drivers changed after experiencing crashes or being charged with violations, and came to match the levels of other drivers not involved in crashes or convicted of violations. A prospective study is needed to clarify whether adverse driving events are related to avoidance and changes in confidence. Of those studies that have evaluated the success of self-regulation using prospective crash data, Ball et al.'s

(1998) results were affected by attrition of the sample, while Lesikar's (2002) study was affected by a small sample size. In both cases, these methodological problems raise doubts about the reliability of the results.

9.4.4 Limitations and Conclusions

A limitation of this study is that the driving behaviour measures are based on self-reports. As noted previously, there may be errors in the estimates of driving exposure (amount of driving done per week) which are likely to be random. Also, as noted, there were apparent omissions in the self-reported crash data, and it is likely that there are omissions for the self-reported traffic violations as well. These could be due to oversights or deliberate omissions. Self-reported measures may also be affected by response bias and it may be that, for some questions, participants tried to give a "good" or socially desirable account of themselves, reporting high driving ability and driving confidence, and low driving avoidance. Volunteer bias may also have affected the results, with older drivers willing to participate in a study involving a driving test and access to official crash data being more likely to be a confident sample of drivers who feel little need to restrict their driving.

Overall, this chapter has demonstrated that this sample of older South Australian drivers was confident about their driving ability and, perhaps based on this confidence, reported a low level of avoidance of difficult driving situations. However, there were still a significant number who did avoid some difficult driving situations, especially parallel parking and driving at night in the rain. The issue in need of resolution is whether those who do lose confidence in their driving ability and restrict their exposure to these difficult situations are those whose health, functional ability or driving ability is in decline. Whether the self-regulation reported in this chapter was linked to an accurate assessment of capabilities by the older drivers themselves is addressed in the following chapter.

CHAPTER 10: THE RELATIONSHIPS BETWEEN FUNCTIONAL AND DRIVING ABILITIES, AND SELF-REGULATION

10.1 Introduction

If "self-regulation" of driving behaviour among older drivers is to be an effective means by which to reduce crash involvement while maintaining mobility, it is important that the older drivers who restrict their driving are those who have a higher risk of crash involvement. The present study assessed this is by investigating the relationships between the self-regulation of driving and both the functional and driving abilities of a sample of older drivers.

As reported in section 4.3.2, previous studies have found that the restriction of driving behaviour is associated with poorer general health (e.g. Kostyniuk et al., 2000), poorer vision (e.g. Owsley et al., 1999) and reduced visual attention (e.g. Ball et al., 1998). There is also some evidence (e.g. Cotrell & Wild, 1999) that the decreased mental status that accompanies dementia decreases the likelihood of appropriate self-regulation, although other studies on older drivers from the general community have found a relationship between decreased mental status and restriction of driving (e.g. Freund & Szinovacz, 2002). Studies examining either the self-regulation or self-ratings of driving ability of older drivers in relation to performance in on-road driving tests have tended not to find a relationship between these variables. However, the samples used in these have consisted of only very old drivers (Charlton et al., 2001; Marottoli & Richardson, 1998) or have featured an over-representation of drivers with dementia (Cushman, 1996). It may be that there is a stronger relationship between avoidance of difficult driving situations and actual driving ability among drivers aged over 60 who are recruited from the general community.

In light of these previous findings, it was expected that those participants who regulated their driving behaviour would be those whose health, and functional and driving abilities were poorer. Therefore, it was hypothesised that poorer general health, and lower functional and driving ability, would be associated with lower self-ratings of driving ability, lower confidence when driving in difficult situations (e.g. in the rain at night) and greater avoidance of difficult driving situations. It was also expected that self-ratings of vision would decrease with declines in performance on objective tests of vision and that self-ratings of dual task ability would decrease with declines in actual dual task performance. Finally, as was done for on-road driving performance (section 8.3.4), the best predictors of self-regulation (overall avoidance of difficult driving situations) were identified using a linear regression procedure, with health and functional measures as the predictor variables.

The questionnaire measures examined in this chapter were taken from the Driver Mobility Questionnaire (refer to section 6.2.2.1 for a detailed description) and include self-ratings of driving ability, vision and dual task ability, confidence when driving in various difficult driving situations, and avoidance of these situations. The health measures were also taken from the Driver Mobility Questionnaire and include self-reported general health (based on self-reported medical conditions and the extent to which these conditions affected daily functioning), self-reported prescription medication use, and use of medications potentially hazardous to driving. The functional measures were self-reports of depressed mood, state anxiety, and trait anxiety, and objective tests of neck mobility, visual acuity (left eye, right eye, binocular), contrast sensitivity (left eye, right eye, binocular), visual field (left, right, total), mental status, speed of information processing, spatial memory, and visual attention (reaction time and detection error scores on the CVAT) (see section 6.2.2.2 for details of the functional tests). Measures of divided attention, based on reaction time performance on the CVAT, were also developed specifically to enable comparisons with self-ratings of dual task ability. Divided attention scores for the primary task were calculated by dividing primary task reaction times in the dual task conditions by those in the single task condition. Similarly, divided attention scores for the secondary task were calculated by dividing secondary task reaction times in the dual task conditions by those in the single task conditions. These calculations were done separately for the conditions with and without visual distracters on the secondary task. This procedure gave a total of four divided attention scores. These were divided attention for: the primary task without visual distracters on the secondary task, the primary task with visual distracters on the secondary task, the secondary task without visual distracters, and the secondary task with visual distracters. Finally, driving ability was measured using the weighted error score on the on-road driving test (see section 6.2.2.3 for details).

10.2 Analyses

Pearson's Product Moment Correlations were calculated between general health, results on the functional and driving tests, and responses on the Driver Mobility Questionnaire. These correlations are presented separately for self-ratings of abilities, confidence in difficult driving situations and avoidance of difficult driving situations (Descriptive statistics for the health measures and functional and driving abilities were provided in section 8.3.1, while those for the responses on the Driver Mobility Questionnaire were provided in section 9.3.1). Hierarchical regression analyses were used to test the strength of significant relationships between avoidance of difficult driving situations and health and functional measures, after controlling for age. These analyses were only conducted for driving avoidance because this was the only questionnaire measure found to be significantly related to age (see section 9.3.2). All correlational analyses used an alpha level of .01. As noted previously, this conservative alpha level was chosen to guard against the increased likelihood of Type I errors resulting from multiple comparisons. Also, the size of correlations was evaluated according to Cohen's (1992) classifications of small (between .1 and .3, accounting for between 1 and 9% of the variance), medium (between .3 and .5, accounting for between 9 and 25% of the variance) and large (over .5, over 25% of the variance). An exploratory analysis to identify the best predictors of self-regulation (overall avoidance of difficult driving situations) was conducted using a linear regression procedure, with a stepwise method of entry and the conventional entry criterion of alpha = .05. Only those variables correlated with overall driving avoidance at the level of $p < .01$ were used in the regression analysis.

10.3 Results

10.3.1 Self-Ratings of Abilities

Pearson's Correlation coefficients were calculated between all health and functional measures and participants' self-ratings of driving ability. The findings from this procedure are provided in Table 10.1, which shows that general health and indices of depressed mood and anxiety were more closely related to self-ratings of driving ability than the majority of functional measures. Of the functional measures, only total neck mobility was significantly correlated with self-rating of driving ability. General health shared a medium-sized correlation with self-ratings of driving ability but all other correlations were in the small range.

Table 10.1
Correlations between self-ratings of driving ability and health and functional measures (N = 104)

Test	Correlation with self-rated driving ability
Health	
General health	-.37**
Medication use	-.16
Hazardous medication	-.15
Depressed mood	
Geriatric Depression Scale	-.28*
Anxiety	
State Anxiety	-.21
Trait Anxiety	-.29*
Physical functioning	
Total neck mobility	.29*
Vision	
Visual acuity, left eye	-.06
Visual acuity, right eye	-.07
Visual acuity, binocular	-.17
Contrast sensitivity, left eye	.01
Contrast sensitivity, right eye	.04
Contrast sensitivity, binocular	.11
Visual field, left eye	.10
Visual field, right eye	.13
Total visual field	.14
Mental status	
3MS	-.04
MMSE	-.05
Speed of info processing	
Symbol Digit	.08
Spatial memory	
Total Spatial Span	.16

Note: 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination
* $p < .01$, ** $p < .001$

The relationship between self-rated driving ability and attention was also determined using correlation coefficients. Table 10.2 shows the correlations between self-rated driving ability and the reaction time and detection error scores from the CVAT. Only detection errors in dual task conditions were included in the analysis because of low reliability for detection error scores in the single task conditions (see section 7.3.2). It can be seen that there were no significant correlations between visual attention and self-ratings of driving ability.

Table 10.2

Correlations between CVAT median reaction times and detection error scores, and self-ratings of driving ability (N = 104)

Test	Correlation between reaction time score and self-rating	Correlation between detection error score and self-rating
Single task		
Primary	-.06	
Secondary, no visual distracters	-.05	
Secondary, visual distracters	-.13	
Dual task		
Primary, no visual distracters on secondary	-.05	.04
Secondary, no visual distracters	-.09	.05
Primary, visual distracters on secondary	-.03	-.04
Secondary, visual distracters	-.25	-.23

Note. CVAT =Computerised Visual Attention Test
**p* < .01, ***p* < .001

It was hypothesised that self-ratings of vision would be related to objective measures of vision (visual acuity, contrast sensitivity, visual field). Contrary to expectations, no measures of vision were found to be significantly correlated with self-ratings of vision (see Table 10.3).

Table 10.3

Correlations between vision test scores and self-ratings of vision (N = 104)

Test	Correlation with self-rating of vision
Visual acuity, left eye	-.18
Visual acuity, right eye	-.18
Visual acuity, binocular	-.16
Contrast sensitivity, left eye	.03
Contrast sensitivity, right eye	.06
Contrast sensitivity, binocular	.16
Visual field, left eye	.01
Visual field, right eye	.08
Total visual field	.06

* *p* < .01, ** *p* < .001

Self-ratings of dual task ability were compared to four measures of divided attention obtained from the CVAT. Table 10.4 shows that the means and standard deviations for the four measures of divided attention were largely consistent across the four different conditions, with reaction times increasing by 10 to 20% on average when division of attention was required (i.e. divided attention scores of 1.1 to 1.2). It can also be seen that participants' self-rated dual task ability was only correlated with their actual divided attention performance for the secondary task with visual distracters. Thus, participants who were most detrimentally affected by having to perform this difficult secondary visual attention task (detecting cars embedded within visual distracters) while also performing a competing primary task (X detection) were those who were more likely to report lower self-ratings for dual task ability. This provides some support for the hypothesis that self-ratings of dual task ability would be related to actual dual task ability.

Table 10.4
CVAT divided attention scores: means, standard deviations, and correlations with self-ratings of dual task ability (N = 104)

Divided attention score	Mean (*SD*)	Correlation with self-rated dual task ability
Primary task, without visual distracters on the secondary task	1.1 (0.1)	.08
Primary task, with visual distracters on the secondary task	1.1 (0.1)	.09
Secondary task, without visual distracters	1.2 (0.1)	-.14
Secondary task, with visual distracters	1.2 (0.1)	-.36**

Note. CVAT = Computerised Visual Attention Test
* $p < .01$, ** $p < .001$

The relationship between self-ratings of driving ability and actual driving ability was also assessed using correlations. It was found that on-road driving test performance was not significantly correlated with self-ratings of driving ability ($r = -.14$, $p = .189$). Self-ratings of vision were also not significantly related to on-road driving test performance ($r = -.04$, $p = .712$) but there was a significant correlation between self-ratings of dual task ability and driving test performance ($r = -.30$, $p = .004$). This means that those whose actual driving ability was poorer tended to report poorer ability to perform two tasks simultaneously but not poorer perceived driving ability or vision.

10.3.2 Driving Confidence

It was hypothesised that lower confidence in difficult driving situations would be related to poorer health, and poorer functional and driving abilities. The correlations between overall driving confidence and functional measures are provided in Table 10.5. It can be seen that the measures most strongly correlated with driving confidence were measures of physical health and mood. Poorer general health, depressed mood, and higher trait anxiety were significantly associated with reduced driver confidence, with correlations in the medium range. In contrast, none of the functional ability measures were significantly correlated with confidence.

The prediction that reaction times and detection errors on the CVAT would be related to driving confidence was also tested using correlation coefficients. Table 10.6 shows that only two of the seven reaction time measures correlated significantly with overall driving confidence, these being reaction time on the secondary task in the two dual task conditions (both medium-sized correlations). As expected, longer reaction times were associated with lower driving confidence. Again, for detection errors, only scores in the dual task conditions were used in the analysis. Only one of the four detection error scores (secondary task in the dual task condition, featuring visual distracters) was significantly related to driving confidence. A greater number of detection errors on this task was associated with lower driving confidence.

Table 10.5

Correlations between overall driving confidence and health and functional measures (N = 104)

Test	Correlation with overall driving confidence
Health	
General health	-.30*
Medication use	-.24
Hazardous medication	-.12
Depressed mood	
Geriatric Depression Scale	-.33**
Anxiety	
State Anxiety	-.18
Trait Anxiety	-.41**
Physical functioning	
Total neck mobility	.13
Vision	
Visual acuity, left eye	-.11
Visual acuity, right eye	-.22
Visual acuity, binocular	-.20
Contrast sensitivity, left eye	.17
Contrast sensitivity, right eye	.21
Contrast sensitivity, binocular	.24
Visual field, left eye	.07
Visual field, right eye	.23
Total visual field	.18
Mental status	
3MS	.12
MMSE	.10
Speed of info processing	
Symbol Digit	.20
Spatial memory	
Total Spatial Span	.12

Note. 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination
* $p < .01$, ** $p < .001$

Table 10.6

Correlations between median reaction times and detection error scores on the CVAT and overall driving confidence (N = 104)

Test	Correlation between reaction time and confidence	Correlation between detection error score and confidence
Single task		
Primary	-.24	
Secondary, no visual distracters	-.17	
Secondary, visual distracters	-.16	
Dual task		
Primary, no visual distracters on secondary	-.18	-.07
Secondary, no visual distracters	-.30*	.01
Primary, visual distracters on secondary	-.16	-.15
Secondary, visual distracters	-.32*	-.35**

Note. CVAT = Computerised Visual Attention Test
*$p < .01$, ** $p < .001$

The relationship between confidence when driving in difficult situations and on-road driving ability was also assessed using correlations, which are shown in Table 10.7. It can be seen that performance in the on-road driving test was moderately correlated with confidence when driving at night and at night in the rain, and correlated to a lesser degree with confidence driving in the rain. There was only a trend towards lower overall driving confidence with poorer performance on the driving test ($p = .015$). All correlations were in the expected direction, with poorer driving test performance (more errors on the on-road driving test) associated with lower driving confidence.

Table 10.7
Correlations between confidence in difficult driving situations and driving performance (n = 90)

Confidence measure	Correlation with driving ability
In the rain	-.29*
Alone	-.04
Parallel parking	-.10
Right turns	-.07
Freeways	-.11
High traffic roads	-.17
Rush hour	-.22
At night	-.36**
At night in rain	-.40**
Overall confidence	-.26

* $p < .01$, ** $p < .001$

10.3.3 Driving Avoidance

The relationship between functional abilities and the avoidance of difficult driving situations (a measure of driver self-regulation) was also examined using correlations (refer to Table 10.8). It can be seen that driving avoidance was only related to three variables, such that increased avoidance was reported by those with poorer general health, greater medication use, and worse right eye visual acuity, with the relationships being small to moderate in size. This suggests that avoidance of difficult driving situations was related to health and some aspects of vision.

Table 10.8

Correlations between overall driving avoidance and health and functional measures (N=104)

Test	Correlation with overall driving avoidance
Health	
General health	.32**
Medication use	.27*
Hazardous medication	.06
Depressed mood	
Geriatric Depression Scale	.08
Anxiety	
State Anxiety	.13
Trait Anxiety	.21
Physical functioning	
Total neck mobility	-.09
Vision	
Visual acuity, left eye	-.06
Visual acuity, right eye	.25*
Visual acuity, binocular	.08
Contrast sensitivity, left eye	-.13
Contrast sensitivity, right eye	-.23
Contrast sensitivity, binocular	-.12
Visual field, left eye	.12
Visual field, right eye	-.14
Total visual field	-.02
Mental status	
3MS	-.03
MMSE	.02
Speed of info processing	
Symbol Digit	-.18
Spatial memory	
Total Spatial Span	-.07

Note. 3MS = Expanded Mini Mental State Examination, MMSE = Mini Mental State Examination
* $p < .01$, ** $p < .001$

As age was found to be related to driving avoidance (see section 9.3.2), it was necessary to investigate whether the functional measures that were related to driving avoidance remained so after controlling for age. This was done with hierarchical regression analyses, using overall driving avoidance as the dependent variable, and age (entered at step 1) and the significant variables from Table 10.8 (entered at step 2) as predictors. Table 10.9 shows that general health and medication use both predicted overall driving avoidance, independently of age. However, right eye visual acuity only approached significance as a predictor of driving avoidance after the effects of age had been controlled.

Table 10.9

Results of hierarchical regression analyses examining the contributions of functional measures to the prediction of overall driving avoidance, after controlling for age (N = 104)

Variables	*B*	Adj R^2	ΔR^2	ß	*t*
Age	0.19	.058	.058	.219	2.36
General health	0.79	.132	.074	.289	3.11*
Age	0.22	.058	.058	.246	2.66*
Medication use	0.79	.117	.059	.260	2.80*
Age	0.18	.058	.058	.203	2.07
Visual acuity, right eye	0.17	.084	.026	.196	1.99

* $p < .01$, ** $p < .001$

It was hypothesised that difficult driving situations would be avoided more by those with poorer visual attention abilities. To test this, correlations were calculated between driving avoidance and CVAT performance, using all seven reaction time scores but, again, only the detection error scores from dual task subtests. Table 10.10 reveals that two of the seven reaction time scores and one of the four detection error scores on the CVAT were significantly correlated with driving avoidance, with longer reaction times and greater detection errors, as expected, being associated with greater overall driving avoidance. Two of the measures significantly correlated with driving performance were for secondary task performance on the CVAT subtest requiring dual task performance (divided attention), with visual distracters on the secondary task (selective attention). These correlations were in the small to moderate range.

Once again, hierarchical regression analyses were conducted to assess whether the apparent link between visual attention and driving avoidance existed independently of the confounding effects of age, with avoidance of difficult driving situations as the dependent variable, and age (entered at step 1) and the CVAT measures (entered at step 2) as predictor variables. Table 10.11 shows that two of the three CVAT measures continued to predict driving avoidance after the effects of age had been taken into account. Therefore, there is evidence that visual attention was related to driving avoidance, independently of age.

Table 10.10

Correlations between overall driving avoidance and median reaction times and detection error scores on the CVAT (N = 104)

Test	Correlation between reaction time and confidence	Correlation between detection error score and confidence
Single task		
Primary	.25	
Secondary, no visual distracters	.28*	
Secondary, visual distracters	.14	
Dual task		
Primary, no visual distracters on secondary	.14	.04
Secondary, no visual distracters	.21	.10
Primary, visual distracters on secondary	.11	.01
Secondary, visual distracters	.28*	.35**

Note. CVAT = Computerised Visual Attention Test
*$p < .01$, ** $p < .001$

Table 10.11

Results of hierarchical regression procedures examining the contributions of CVAT measures to the prediction of overall driving avoidance, after controlling for age (N = 104)

Variables	B	Adj R^2	ΔR^2	ß	t
Age	0.21	.058	.058	.236	2.53
Reaction time to cars, single task, no visual distracters	0.03	.114	.056	.254	2.73*
Age	0.16	.058	.058	.183	1.81
Reaction time to cars, dual task, visual distracters	0.01	.087	.029	.209	2.07
Age	0.16	.058	.058	.178	1.87
Detection errors for cars, dual task, visual distracters	0.20	.135	.077	.302	3.17*

Note. CVAT = Computerised Visual Attention Test; cars = stimulus to be detected in the CVAT secondary task
* $p < .01$, ** $p < .001$

A linear regression analysis was performed to identify the functional measures that best predicted driving avoidance. A stepwise method of entering the variables was used, with the candidate predictor variables including age and all of the functional variables that were significantly correlated with overall driving avoidance, these being: general health, medication use, right eye visual acuity, CVAT reaction time for the secondary task in the single task condition without visual distracters, and both CVAT reaction time and target detection errors for the secondary task in the dual task condition with visual distracters. The results of this analysis are summarised in Table 10.12, while an inter-correlation matrix for the predictor variables is provided in Appendix 10. It can be seen that poorer target detection for the secondary task in the dual task condition with visual distracters (a measure of selective and divided attention) was a better predictor of overall driving avoidance than any other functional measure. Another score from the CVAT (reaction time for the secondary task in the single task condition, without visual distracters - a measure of simple visual attention for peripheral stimuli) also made an independent, significant contribution to prediction of driving performance. Greater medication use and poorer right eye visual acuity were also independent, significant predictors of driving avoidance. Notably, age was not found to make a significant contribution. The total proportion of variance in overall driving avoidance accounted for by the regression equation (using the Adjusted R squared value) was 24%.

Table 10.12
Multiple regression predicting overall driving avoidance using functional measures as predictor variables (N=104)

Variables in the model	B	Adj R^2	ΔR^2	ß	t
Percentage of detection errors for the secondary task in the dual task condition, with visual distracters[1]	0.17	.114	.114	.252	2.80**
Medication use	0.74	.161	.047	.244	2.80**
Visual acuity, right eye	0.22	..218	.057	.262	3.03**
Reaction time for the secondary task in the single task condition, without visual distracters[1]	0.02	.241	.023	.181	2.01*

[1] Subtest from the Computerised Visual Attention Test
* $p < .05$, ** $p < .01$

The relationship between on-road driving ability and self-regulation of driving was ascertained by calculating correlations between driving test performance and the avoidance of difficult driving situations. Table 10.13 shows that overall avoidance was not significantly correlated with on-road driving test performance. However, significant correlations were found for the avoidance of specific driving situations, namely driving in the rain, driving at night, and driving at night in the rain.

Table 10.13
Correlations between avoidance of difficult driving situations and driving test performance (n = 90)

Avoidance measure	Correlation with driving ability
In the rain	.33**
Alone	-.01
Parallel parking	.05
Right turns	.09
Freeways	-.02
High traffic roads	.00
Rush hour	-.10
At night	.34**
At night in rain	.35**
Overall avoidance	.20

* $p < .01$, ** $p < .001$

10.4 Discussion

The analyses presented in this chapter have provided some evidence that older drivers adjust their driving in response to deficits in functional and driving ability. However, the relationships between avoidance of difficult driving situations and functional and driving abilities were not strong, suggesting that the self-regulatory practices of older drivers may be less than optimal.

10.4.1 Self-Ratings of Ability

Participants' perceptions of their own driving ability were more strongly related to general health and mood (depressed mood and anxiety) than functional abilities. Indeed, total neck mobility was the only functional variable that was related to perceived driving ability. Furthermore, perceived driving ability was not related to *actual* driving ability. Thus, lower self-ratings of driving ability are not given by those with poorer functional or driving abilities but by those who have been diagnosed with more medical conditions, or who are more anxious or depressed. This finding that older drivers' perceived driving ability is not related to their actual driving ability is consistent with previous studies by Marottoli and Richardson (1998), which was based on an older sample, and by Cushman (1996), which was based on a sample that included a large proportion (35%) of drivers with dementia. If drivers are unable to detect declines in driving ability, then self-regulation in response to declining ability would be unlikely.

Self-ratings of vision were found to be unrelated to measures of actual vision. This is consistent with a study by Stalvey and Owsley (2000), in which participants were not able to detect declines in their visual functioning. Specifically, they found that 70% of participants with deficits in vision or visual attention reported that their vision was "good" or "excellent". Holland And Rabbitt (1992) also found no correlation between self-rated and actual vision among a sample of adults aged over 50. However, there were very few drivers in the present study whose vision would be regarded as "impaired". This may be because drivers over the age of 70 in South Australia must obtain a yearly medical certificate establishing fitness to drive, one of the requirements of which is adequate visual acuity (the legal level in Australia is 6/12 or better). These screening procedures would decrease the likelihood of older adults driving when they have a visual impairment. Any drivers who did have visual impairment, and were aware of it, would be less likely to volunteer to participate in a driving study that included vision testing. Caution must be exercised, therefore, in the interpretation of the finding of no relationship between self-rated and objectively-measured vision. A better test of the relationship between self-ratings of vision and actual vision could be conducted with a sample including participants whose vision is poor enough to preclude holding a driver's licence.

Interestingly, the strongest relationship between a self-rated and an actual ability was for dual task performance. Perceived ability to perform more than one task simultaneously was related to the objectively-measured ability to divide attention on a CVAT subtest that required the detection of stimuli in the peripheral visual field in the presence of visual distracters. This was the most difficult of the visual attention tasks and so it is encouraging that it was the one most closely related to self-assessments of dual task ability. Furthermore, perceived dual task ability was the only self-rating measure that was significantly related to on-road driving ability. It may be that drivers with declining driving ability first notice deficits in their ability to perform more than one task simultaneously. This is an important finding, particularly as perceived dual task ability has not been studied previously in research on older drivers.

10.4.2 Driving Confidence

Another way of looking at drivers' self-evaluations is to look at confidence when driving. The Driver Mobility Questionnaire included a question in which participants had to rate their confidence when driving in a number of difficult driving situations. If older drivers are responsive to declining abilities, it would be expected that driving confidence would be related to functional and driving abilities. As with perceived driving ability, the variables most strongly related to overall confidence were general health, depressed mood, and trait anxiety. This indicates that the drivers with lower confidence in difficult situations were those with more medical conditions, those who were more depressed, and those with an anxious disposition.

A small number of significant relationships were also found with the visual attention variables, especially for the CVAT subtest involving both selective and divided attention to stimuli in the peripheral visual field (secondary task performance in a dual task condition featuring visual distracters). Overall driving confidence was found to be moderately related to both the speed and accuracy scores for this task. This was the most complex component task of the CVAT and its relationship with driving confidence suggests that older drivers may lose confidence in their driving in response to the types of driving difficulties caused by declines in attentional abilities. The finding that there were significant relationships between driving confidence and measures of visual attention contradicts the findings of a study by Stalvey and Owsley

(2000) in which 82% of drivers with poor vision or visual attention reported no difficulty with challenging driving situations.

The relationship of most interest, namely that between driving confidence and on-road driving ability, was not found to be significant. This finding is consistent with that of Marottoli and Richardson (1998), although the correlation in their study of .11 ($p < .05$) was smaller than that found in the present study ($r = -.26$, p=.015). (Note: the difference in the direction of these correlations was artefactual). The present study additionally considered specific driving situations, and it was found that poorer driving ability was associated with lower confidence when driving in the rain, at night, and at night in the rain. Thus, the apparent lack of a relationship between overall driving confidence and driving ability conceals relationships between driving ability and confidence *in specific situations*. This is the first study to investigate driving confidence in sufficient depth to find these relationships with driving ability.

10.4.3 Driving Avoidance

The variable of most interest to an investigation of self-regulation is the avoidance of difficult driving situations. If self-regulation occurs in response to declines in functional and driving ability, then performance on functional and driving tests would be expected to correlate with measures of driving avoidance. One of the strengths of this study was that it provided a test of the relationships between functional and driving measures and self-regulation using a sample of drivers with a wide age range and largely recruited from the general community.

Driving avoidance shared moderate relationships with general health and a measure of selective and divided attention to stimuli in the peripheral visual field (detection errors for the secondary task in the dual task condition with visual distracters on the CVAT). Small correlations were found with medication use, right eye visual acuity, and two CVAT reaction time scores: these being simple attention to stimuli in the peripheral visual field (reaction times on the secondary task in the single task condition without visual distracters), and selective and divided attention to stimuli in the peripheral visual field (reaction times on the secondary task in the dual task condition with visual distracters). Therefore, self-regulation was found to be linked, albeit not strongly, with health, vision, and visual attention. These findings are consistent with those reported previously between self-regulation and health (Kostyniuk et al., 2000; Raitanen et al., 2003), vision (Ball et al., 1998; Hennessy, 1995; Owsley et al., 1999) and visual attention (Ball et al., 1998; Hennessy, 1995). The lack of a relationship between mental status and self-regulation is consistent with suggestions that those with lower mental status lack insight and so do not respond to their impairment by regulating their driving behaviour (e.g. Adler et al., 1999; Ball et al., 1998; Eberhard, 1996).

When attempting to identify those variables that best predict overall driving avoidance, the variables with the highest predictive power were: a detection error measure of selective and divided attention for stimuli in the peripheral visual field, medication use, visual acuity for the right eye, and a reaction time measure of simple visual attention to stimuli in the peripheral visual field. Of interest is the finding that driving avoidance was predicted more by health and functional measures than it was by age. This suggests that self-regulation is more likely to be a response to a decline in functioning than to advancing age. This is consistent with Stutts (1998) who found reduced driving exposure and avoidance of difficult driving situations were better predicted by cognitive and visual measures than by age. That two of the four variables that predicted overall driving avoidance were attention measures suggests that declining attention may play an important role in the self-regulatory practices of older drivers, while the significant relationship between medication use and driving avoidance could have been due to the association of medication use with the number and severity of medical conditions.

The finding that visual acuity in the right eye was the visual measure most strongly related to driving avoidance is also of interest, given findings by Ivers et al. (1999) that self-reported crashes were more common among Australian drivers with lower visual acuity in the right eye. This was explained by the authors as being a result of the importance of the right eye for detecting hazards on the right side of the visual field in a jurisdiction where people drive on the left-hand side of the road. It could be that difficulties associated with detecting hazards on the right, associated with lower right eye acuity, lead to older drivers losing confidence in driving and instigating self-regulation. Consistent with this interpretation is that the visual attention measures related to driving avoidance in the regression equation were for the task of detecting targets (cars) in the right periphery rather than responding to targets (Xs) in the central field of vision, although this could also be related to the car detection task being the secondary task in the visual attention test.

Although measures of health, vision and attention were found to predict driving avoidance, the amount of variance that was explained by these variables was only 24% (using the adjusted R^2). Given the breadth of measures used in this study, this finding demonstrates the complexity involved in a person's decision to regulate his or her driving behaviour. It also seems that functional variables only play a limited role in such behaviour. It may be that additional variance could be explained by factors related to lifestyle (e.g. extent of social activities) and personality (e.g. conscientiousness).

The central issue of the thesis is whether older drivers limit their driving in a manner consistent with their driving abilities. This study was designed to address this issue by providing an assessment of the relationship between self-regulation and on-road driving ability in a sample of community-dwelling older drivers. The result of this assessment was that on-road driving ability was *not* significantly correlated with overall driving avoidance, suggesting that older drivers, as a group, do not appropriately self-regulate their driving. Previous studies of self-regulation (Charlton et al., 2001; Cushman, 1996; Marottoli & Richardson, 1998) have also found that self-regulation and driving ability are not related but these studies have been based on samples either of very old drivers or have included a large proportion (over 30%) of drivers who had been diagnosed with dementia. Therefore, one important result of the present study is that these previous findings have now been replicated in a sample of generally healthy, community dwelling drivers aged over 60.

Another important finding was that stronger correlations between driving ability and avoidance were found for a number of specific driving situations (rain, night, night in the rain). Therefore, as with driving confidence, the apparent lack of a relationship between driving avoidance and driving ability appears to conceal significant relationships for specific situations. Older drivers *do* self-regulate in a manner consistent with driving ability *but only for a small number of specific situations*. These driving situations (rain, night, night in the rain) were those for which driving ability was related to driving confidence, and so it could be that these situations are those in which older drivers with poorer driving ability are most likely to experience difficulty, and that they respond to this difficulty with avoidance. This finding, that driving ability is related to the avoidance of a number of specific difficult driving situations, is a new one in the road safety literature, as previous research has not investigated self-regulatory practices in the same depth.

10.4.4 Limitations

There were some limitations of this study that necessitate some caution when interpreting the findings. First, the confidence and avoidance measures were self-reported and it may be that some participants tried to give a 'good' or socially desirable account of themselves, reporting high perceived driving ability, high driving confidence and low driving avoidance. This may have affected the analyses of relationships between these variables and the functional and driving measures. Also, cross-sectional findings for the relationships between functional measures and driving behaviour may not be the same as would be found in a longitudinal study.

Another limitation is that the assessment of on-road driving ability did not assess performance in a number of the difficult driving situations that were the focus of Driver Mobility Questionnaire items regarding driving confidence and driving avoidance. Specifically, the driving test did not asses driving in the rain, alone, on freeways, at peak hour, at night, or at night in the rain. It also did not assess reverse parallel parking. It is likely that the driving performance scores of participants who often avoided difficult driving situations would have been poorer if their driving was assessed in these situations. Therefore, the likely result of this limitation of the driving test is that the relationships reported in this study between driving ability and both confidence in, and avoidance of, difficult driving situations under-estimate the strength of the true relationships. However, the driving tests did assess performance in a wide variety of traffic conditions, ranging from quiet streets to busy main roads. Assessing driving performance in all of the difficult driving situations would have been impractical. Also, as noted by Lundberg et al. (1997, p34), given that some older drivers do restrict their driving in difficult driving situations, it would be "inappropriate to demand more of the elderly than they do of themselves" when assessing their on-road driving ability.

A final limitation is that the results may be affected by volunteer bias. Those volunteering for a study involving an assessment of on-road driving performance may be more likely to be confident about their driving ability. Drivers volunteering for the study who have deficits in driving ability may, therefore, mainly be those who are unaware of these deficits. This would, in turn, reduce the relationships between on-road driving ability and variables such as self-reported driving ability, driving confidence, and driving avoidance. The correlations between these variables reported in this study may again, therefore, under-estimate the strength of the real relationships. As noted previously (refer to section 8.4.2), the problem of volunteer bias is difficult to control for, as random sampling in tests of on-road driving ability is impractical (Lee et al., 2003).

10.4.5 Conclusions

Measures of general health and selective and divided attention were the variables in the present study that were most strongly related to self-regulation of driving behaviour. However, functional measures were limited in the extent to which they predicted self-regulation, and self-regulation was not significantly related to driving ability. Although the nature of the driving test and volunteer bias may have contributed to the latter finding, it must be concluded that self-regulation is not closely related to drivers' abilities. Therefore, it would be useful to compare the relationships between functional measures and driving ability with those between functional measures and self-regulation. Such a comparison would assist in identifying the factors that negatively influence driving ability but which are not associated with the avoidance of difficult driving situations. This, in turn, would indicate some of the factors that older drivers need to consider more carefully when making decisions about their driving practices. This comparison is conducted in the final chapter of this thesis, as part of an overall summary of the findings.

CHAPTER 11: SUMMARY AND CONCLUSIONS

11.1 Introduction

The aim of this thesis was to examine the extent, and correlates, of self-regulation of driving behaviour among a sample of South Australian older drivers (aged 60 or more). The first study involved an analysis of official crash statistics in South Australia over a period of five years, focusing on age differences for crash numbers, crash characteristics, and the conditions in which crashes occur (Chapter 2). This was done to find out whether the patterns of crash involvement for older drivers in South Australia were similar to those previously reported in the literature for other regions (as described in Chapter 1).

Following a review of the literature on older drivers (Chapters 3 and 4), the second study, described in Chapter 5, involved pilot testing a measure developed specifically for assessing the visual attention of older adults (the Computerised Visual Attention Test - CVAT). This test assesses visual attention by measuring target detection and reaction time for central and peripheral stimuli, and in conditions requiring selective and divided attention. The third study involved assessing the test-retest reliability, construct validity and predictive validity of the CVAT in a sample of 20 older drivers (Chapter 7). CVAT measures were found to have good test-retest reliability and to be more closely related to on-road driving ability than standard measures of attention.

The fourth study involved an examination of the driving behaviour and attitudes of 104 drivers aged over 60, with avoidance of difficult driving situations providing an index of self-regulation. These drivers also completed a battery of functional tests measuring psychological factors, vision, physical functioning, various cognitive abilities and attention (the CVAT). Ninety participants additionally completed an on-road assessment of driving ability. All of these measures were described in Chapter 6. This comprehensive study of older drivers enabled an assessment of the relationships between functional and driving abilities (Chapter 8), the extent of self-regulation practised by older drivers (Chapter 9), and the relationships between self-regulation and both functional and driving abilities (Chapter 10).

This final chapter begins with a brief summary of the findings of the first study, in which the crash involvement of older drivers in South Australia was analysed. Following this, the driving attitudes and behaviour of a sample of older drivers in South Australia, fully described in Chapter 9, are briefly summarised. Finally, there will be a comparison, for each of the functional measures, between the extent to which they were related to on-road driving ability and the extent to which they were related to the self-regulation of driving behaviour. This comparison of the findings from Chapters 8 and 10 is designed to determine whether there are functional measures that are related to driving ability but which do not seem to have any influence on the driving decisions of older drivers. Such a comparison is unique in the road safety literature.

11.2 Older Driver Crash Involvement in South Australia

In Chapter 2, it was shown that the patterns of crash involvement for older drivers in South Australia were similar to those found previously in other comparable regions (elsewhere in Australia, USA, UK, Europe). In terms of the *number* of crashes, it was found that older drivers were involved in fewer crashes than young (16-34) and middle-aged (35-54) drivers but that older drivers had higher crash rates than middle-aged drivers on a per kilometre driven basis. However, the latter finding must be treated with some caution because of limitations of the travel distance data used for this analysis. Specifically, the data provided by the Australian Bureau of Statistics were from a vehicle-based, rather than a driver-based, survey and were too unreliable to use for drivers aged over 84. Despite these problems, the findings were consistent with those previously reported in the literature (Frith, 2002; Lyman et al., 2002; Maycock, 1997; OECD, 2001; Ryan et al., 1998), suggesting that South Australian older drivers are typical of older drivers in terms of crash involvement.

The *characteristics* of the crashes that South Australian older drivers were involved in were also analysed. It was found that, relative to crash-involved drivers in younger age groups, older crash-involved drivers were *more* likely to be involved in crashes that resulted in serious or fatal injury; be seriously or fatally injured themselves; be involved in right turn collisions; be turning at the time of the crash; be turning right in right turn collisions; disobey a traffic signal, Give Way or Stop Sign prior to the crash; and be deemed responsible by police for their crashes. Older drivers were *less* likely to have been exceeding the legal blood alcohol limit or the legal speed limit when involved in crashes. These findings are all similar to those reported previously in Australia (Ryan et al., 1998), the USA (Council & Zegeer, 1992; Eberhard, 1996; Partyka, 1983; Preusser et al., 1998), Canada (Cooper, 1990a; Daigneault et al., 2002b) and Europe (Fontaine & Gourlet, 1992; Hakamies-Blomqvist, 1993; Maycock, 1997), again showing that South Australian older drivers are typical of those in other regions; in this context, with respect to the types of crashes they experience.

The third part of the crash database analysis was concerned with the *situations* in which crashes occur. Here, it was found that crash-involved older drivers were less likely than crash-involved drivers in younger age groups to have crashed during peak traffic periods, hours of darkness, or wet weather. These findings replicate those of other studies (Cooper, 1990a; Eberhard, 1996; Fildes, 1997; Hakamies-Blomqvist, 1994; OECD, 2001) and suggest that older drivers may restrict their exposure to these difficult driving situations. This, in turn, suggests the possibility of “self-regulation” of driving behaviour by older drivers. The remainder of the thesis was designed to provide a detailed examination of the self-regulatory driving practices of older drivers.

11.3 Driving Attitudes and Behaviour of Older Drivers

In order to ascertain the extent of self-regulation that is practised by South Australian older drivers, a sample of 104 participants aged over 60 completed a questionnaire (the Driver Mobility Questionnaire) about their driving attitudes and behaviour. This revealed that the older drivers in the study were very mobile, and valued their independence and the maintenance of their lifestyles. There was considerable variation in the amount of driving done by the participants but few drivers restricted the geographical area in which they drove. The majority of drivers had reduced the amount of driving they did in the previous ten years, which was mainly attributed to a lower need for driving. Participants generally perceived their driving ability, vision and dual task ability to be good and reported high levels of confidence in difficult driving situations and low levels of avoidance of these situations. This pattern of results for the questionnaire was broadly consistent with previous research in the area (Burns, 1999; Jette & Branch, 1992; Kline et al., 1992; Owsley et al., 1999; Rabbitt et al., 2002; Stalvey & Owsley, 2000). It was also found that the level of crash involvement of drivers in the sample in the previous five years was typical of older drivers in general, based on the crash statistics analysis presented in Chapter 2. This suggests that the sample of drivers participating in the study was likely to be representative of South Australian older drivers.

Increased *age* was associated with greater avoidance of difficult driving situations (self-regulation) but was not related to self-reported abilities (driving, vision, dual task), driving exposure (days driven per week, trips per week, kilometres driven per week), the geographical area in which driving was done, or overall driving confidence. A relationship between lower confidence and increased age was found only for a small number of specific situations (night driving and driving at night in the rain). The finding of a relationship between age and overall avoidance but not between age and overall confidence is consistent with previous results (Charlton et al., 2003; Forrest et al., 1997; Holland & Rabbitt, 1994; Marottoli & Richardson, 1998; Rabbitt et al., 2002). The lack of a relationship between age and driving exposure is inconsistent with previous findings (Forrest et al., 1997; Maycock, 1997; OECD, 2001) but could be due to inaccurate participant estimates of the amount of driving they did per week.

Gender differences were also apparent, with female drivers having a smaller driving space (geographical area in which driving was done) and being more likely to avoid parallel parking and driving on freeways. Therefore, gender differences were minor but in the expected directions (Burns, 1999; Gallo et al., 1999; Rimmo & Hakamies-Blomqvist, 2002). It will be interesting to see if gender differences are found in future studies, as the driving behaviour of females in more recent cohorts is becoming more like that of their male counterparts (Eberhard, 1996; Hakamies-Blomqvist, 1996; Laapotti, 1991; Weinand, 1996). Gender differences in the cessation of driving have been found to be related to gender differences in lifetime driving experience rather than gender *per se* (Hakamies-Blomqvist & Siren, 2003), and it could be that current gender differences in self-regulation will disappear among newer cohorts in which males and females have shared similar driving patterns throughout their lives.

The relationships between the driving attitudes and behaviour assessed by the questionnaire were also examined. These analyses revealed that overall *confidence* when driving in difficult situations was related to self-ratings of vision and driving ability, the latter consistent with previous findings (Marottoli & Richardson, 1998; Parker et al., 2001), but was most strongly related to self-rated dual task ability. This finding that driving confidence and perceived *dual task* ability were more strongly related than confidence and perceived *driving* ability could be due to older drivers detecting problems with performance of simultaneous tasks when driving prior to detecting any *overall* problems with driving. Confidence was unrelated to driving exposure, contrary to previous findings (Marottoli & Richardson, 1998; Parker et al., 2001; Rabbitt et al., 2002) but, again, this could have been due to inaccurate self-reports of the amount of driving done by participants. Consistent with an earlier study by Marottoli et al. (1998), confidence was unrelated to previous crashes or violations, which may be due to older drivers attributing such events to external or unstable factors. Alternatively, confidence levels may have been higher than average prior to the crashes or violations but may have been reduced after these events to match the levels of drivers not involved in crashes or convicted of violations. Confidence in difficult driving situations was related to avoidance of these situations, with the strongest correlations being for those situations that were reportedly the easiest to avoid (e.g. parallel parking) and the weakest for the situations that were reportedly the most difficult to avoid (e.g. driving alone). The relationship between overall confidence and avoidance had been shown before (Charlton et al., 2003) but the possible mediating effects of the ease of avoidance of specific situations is a new finding.

Greater overall *avoidance* of difficult driving situations (an index of *self-regulation*) was related to lower perceived driving ability and dual task ability but not to perceived quality of vision. This may mean that lower self-ratings of vision affect driving confidence but do not influence self-regulation. Alternatively, it may be that there is a threshold of perceived visual impairment that must be reached before self-regulation of driving occurs. Overall avoidance of difficult driving situations was related, albeit not strongly, to reduced driving space, suggesting that self-regulation may be related to reduced mobility. It could be that avoidance leads to this reduced mobility, or that those who drive less also choose to avoid difficult driving situations.

However, avoidance was not related to reduced driving exposure, suggesting no loss of mobility with self-regulation, although, again, this could be due to inaccurate self-reports of driving exposure. As with confidence, overall avoidance was not related to previous crashes or violations. This finding is difficult to interpret because avoidance may have increased following these crashes or violations, and reached the same level as that of drivers who were not involved in crashes or charged with traffic violations. The most useful test of the relationship between self-regulation and experience of adverse driving events would be one using prospective data. Two studies of this sort (Ball et al., 1998; Lesikar et al., 2002) produced contradictory findings but both were affected by methodological problems that raise doubts about the reliability of the results.

11.4 Relationships Between Functional Measures, Driving Performance and Self-Regulation: A Synthesis of the Findings

The 104 participants who completed the Driver Mobility Questionnaire also completed a battery of functional tests and 90 participants completed an on-road driving assessment. This enabled an assessment of whether driving attitudes and behaviour, particularly self-regulatory practices, were related to health and functional measures, and actual driving ability (see Chapter 10). On-road driving ability was related to perceived dual task ability, confidence when driving in certain situations (in the rain, at night, at night in the rain), and avoidance of these same three situations. Driving ability was *not* related to perceived driving ability, perceived vision, overall confidence in difficult driving situations, or overall avoidance of these situations. The finding that overall avoidance of difficult driving situations was unrelated to performance on the driving test suggests that self-regulation does not occur reliably in response to deficits in driving ability.

Given this lack of a relationship between self-regulation and on-road driving ability, it would be useful to compare the relationships between functional measures and driving ability with those between functional measures and self-regulation. This would identify the factors that negatively influence driving ability but which are not associated with the avoidance of difficult driving situations. These factors would therefore be those that older drivers may need to consider more carefully when making decisions about their driving practices.

The following section considers each of the health and functional measures that were used in the present study, with respect to its relationship with driving ability (full details provided in Chapter 8) and with driving attitudes and behaviour (full details in Chapter 10). If deficits in a health or functional measure are related to poorer driving ability but not self-regulation of driving behaviour, then older adults with deficits in that type of functioning may be a group of drivers who self-regulate *less* than they need to. Conversely, if declines in a health or functional measure are unrelated to driving ability but are related to greater self-regulation, then older adults with deficits in that type of functioning may restrict their driving *more* than they should. The following section makes the above comparisons for health (general health, medication use), mood factors (depressed mood, anxiety), physical functioning (neck mobility), vision (visual acuity, contrast sensitivity, visual field), mental status, speed of information processing, spatial memory, and complex visual attention.

11.4.1 Health and Medication

The correlation between general health and driving ability only approached significance, contradicting claims by a number of authors (Dobbs et al., 1998; Klavora & Heslegrave, 2002; Marottoli, 2002; Wallace & Retchin, 1992; Waller, 1992) that the combination of different medical conditions would be a risk factor for driving difficulties among older drivers. The finding of stronger relationships with driving ability for functional measures, rather than for health, provides empirical support for the argument that functional abilities, rather than medical diagnoses, are of greater importance in the re-licensing process for older drivers (Marottoli et al., 1998; OECD, 2001; Sims et al., 1998; Wallace & Retchin, 1992; Waller, 1992; White & O'Neill, 2000). However, poorer health was moderately related to lower perceived driving ability, lower confidence in difficult driving situations, and greater avoidance of these situations (self-regulation). The finding that poorer health was related to self-regulation of driving is consistent with the literature (Forrest et al., 1997; Kostyniuk et al., 2000; Rabbitt et al., 2002; Raitanen et al., 2003).

These results demonstrate that health is more closely related to driving behaviour than to driving ability. It may be that older adults respond to declining health with alterations of driving behaviour even though these declines in health are, at most, only weakly related to their ability to drive. Although this may mean that older drivers are over-reacting to diagnosed medical conditions, it is still encouraging that poorer health status is related to driving behaviour. Acknowledgement of the presence of medical conditions and their associated symptoms may be a proxy for the evaluation of functional capabilities - evaluations that older adults would have great difficulty undertaking themselves - and so greater self-regulation with poorer health would indirectly provide some degree of relationship between self-regulation and poorer functioning.

Use, at least once per month, of prescription medications was not found to be related to driving ability, nor was use of potentially hazardous medications, although the latter came close to significance. Use of medications, however, was related to confidence when driving in difficult situations and also to avoidance of these situations. Furthermore, medication use was one of four variables to independently predict overall avoidance of difficult driving situations. These results suggest that older drivers may regulate their driving behaviour in response to medication use to a greater degree than is necessary, replicating the results for general health. The relationship between medication use and self-regulation may, in part, be explained by association between greater medication use and a greater number and severity of medical conditions.

When interpreting these findings, it must be remembered that the measures of general health and medication use were based on self-reported information. If participants omitted medical conditions or prescription medications, or understated the extent to which conditions affected their daily functioning, the non-significant trends reported here may underestimate the strength of the true relationships between health measures and driving ability. Given this possibility, and given that acknowledging the symptoms of medical conditions may be a proxy for evaluation of functional capabilities, the appropriate conclusion is that the relationship between self-regulation and health measures is a promising indication of appropriate adjustments to driving behaviour by older drivers.

11.4.2 Mood-Related Factors

None of the mood-related measures (depressed mood, state anxiety, trait anxiety) were related to driving ability, although there was a trend for those with higher depressed mood scores to perform more poorly on the driving test. As there were few participants with scores indicative of depression, it could be that the relationship between depression and driving ability was underestimated by this study. There have been studies conducted previously that have found a relationship between crash involvement and depression among older drivers (Foley et al., 1995; Sims et al., 2000).

With regard to driving attitudes and behaviour, lower perceived driving ability and lower confidence in difficult driving situations were both related to a more depressed mood and an anxious disposition (higher trait anxiety), while avoidance of difficult situations was unrelated to any mood-related measures. There was only a trend for greater driving avoidance by those with an anxious disposition. These results suggest that older drivers who are typically anxious or have a more depressed mood tend to view their driving unfavourably and lack confidence when driving but, despite this, are no more likely to restrict their driving.

It appears that a more depressed mood and anxious disposition are both related to lower perceived driving ability and confidence but are unrelated to actual driving ability and self-regulation. This suggests that these negative mood-related factors may make older drivers think their driving is worse than it is but are not sufficient to prompt alteration of driving behaviour. However, the non-significant trends for the relationship between depressed mood and poorer driving ability, and for the relationship between an anxious disposition and greater driving avoidance, may be worthy of investigation using samples of drivers specifically chosen for higher levels of anxiety and depression than were found in the sample in the present study.

11.4.3 Physical Functioning

The only measure of physical functioning used in the present study was neck mobility, which had previously been found by Marottoli et al. (1998) to be related to the crash involvement of older drivers and by McPherson et al. (1988) to be related to poorer performance by older drivers in an on-road driving assessment. In the present study, however, neck mobility was not found to be related to driving ability, consistent with studies by Odenheimer et al. (1994), Staplin et al. (1998b) and Tarawneh et al. (1993). It was also unrelated to driving confidence and avoidance but was related to perceived driving ability. The latter finding suggests that older drivers may notice restrictions to neck mobility and may think that these restrictions negatively affect their driving ability. However, restrictions in neck mobility do not affect confidence when driving or prompt older adults to restrict their driving. The fact that neck mobility was not related to self-regulation is appropriate given that it was not related to driving ability. It appears that, although restrictions of neck mobility are common among community-dwelling older adults, they are not of great importance in determining driving ability and behaviour. It is possible that only profound deficits in physical functioning that cannot be compensated for with changes to the vehicle one drives prove to be problematic for older drivers.

11.4.4 Vision

Vision was assessed using measures of visual acuity, contrast sensitivity and visual field, with only contrast sensitivity being related to driving ability. Both binocular and left eye contrast sensitivity shared moderate relationships with driving ability and the former was one of four variables to independently predict on-road driving test scores. The importance of contrast sensitivity to driving has been shown previously (Janke & Eberhard, 1998; Wood, 2002a). It is recommended that, if a battery of tests is to be used for the purpose of re-licensing older drivers, a measure of contrast sensitivity should be included. Currently, there is no mention of contrast sensitivity in the Australian guidelines for assessment of fitness to drive (Austroads, 2001).

None of the measures of vision was related to perceived driving ability or driving confidence but there was a relationship between overall driving avoidance and right eye visual acuity. Furthermore, visual acuity in the right eye was one of four variables to make independent contributions to the prediction of driving avoidance. This is consistent with previous findings of relationships between vision and self-regulation (Ball et al., 1998; Hennessy, 1995; Owsley et al., 1999).

Although these findings demonstrate that measures of vision were related to both driving ability and self-regulation of driving among older adults, contrast sensitivity was more important for driving ability whereas visual acuity was of greater importance for self-regulation. Greater use of contrast sensitivity tests in medical assessments, as is recommended given its relationship with driving ability, could possibly increase awareness of contrast sensitivity, which could, in turn, possibly increase the likelihood that self-regulation coincides with declines in this aspect of vision. However, it may be necessary for medical practitioners to take a more active role in discussing vision and driving behaviour, given the finding in the present study that there was no relationship between self-ratings of vision and *actual* vision. That is, older adults may not be capable of detecting declines in their vision, or of evaluating the importance of these declines, and may need guidance from medical practitioners in acknowledging problems with vision and responding to them appropriately.

11.4.5 Mental Status

Deficits in mental status have previously been found to work against appropriate self-regulation of driving due to its association with lack of insight into the loss of driving abilities (e.g. Adler et al., 1999; Ball et al., 1998; Eberhard, 1996). Consistent with this, the present study did not find a relationship between mental status and perceived driving ability, driving confidence, or driving avoidance. However, contrary to expectations, the relationship between mental status and driving ability was only a non-significant trend. The likely explanation for this lack of a relationship between mental status and driving ability is that mental status may be more important among clinical samples, especially drivers with dementia, than among a sample of largely healthy, community dwelling adults.

Given the lack of drivers with dementia in the study sample, conclusions regarding mental status and self-regulation are difficult to draw from the present study. Previous studies using clinical samples have found that drivers do not respond to declines in mental status with self-regulation, despite the fact that such declines are related to losses of driving ability (e.g. Clark et al., 2000; Cushman, 1996; Fitten et al., 1995; Rizzo et al., 2001). This means that drivers with dementia or cognitive impairment comprise a group that needs to be targeted by any interventions aiming to promote self-regulation. These drivers are likely to experience losses of driving ability that they will not detect or respond to without intervention by a carer or medical practitioner.

11.4.6 Speed of Information Processing

Speed of information processing was measured with the Symbol Digit Modalities Test and, as expected, was related to driving ability, although the relationship was not significant after the effects of age were controlled. This suggests that, among a sample of drivers with little cognitive impairment, this measure largely provides an index of age-related slowing in information processing.

Speed of information processing was unrelated to driving attitudes and behaviour. The avoidance of difficult driving situations and speed of information processing were both related to age but not each other.

Therefore, slowed information processing was related to poorer driving ability but not to greater avoidance of difficult driving situations, and so may be indicative of drivers who do not respond to reduced driving ability with self-regulation. The Symbol Digit Modalities Test is quick and easy to administer and so appears to be a good test for assessing speed of information processing in this context, and for identifying drivers who may need to alter their driving behaviour. Additionally, the Symbol Digit tends to be associated with cognitive impairment (Spreen & Strauss, 1997), which is also related to poorer driving ability but not greater self-regulation.

11.4.7 Spatial Memory

Spatial memory, as measured by Total Spatial Span, was related to driving ability and also made an independent contribution to its prediction. The relationship between visuospatial memory and on-road driving ability has been shown before among older drivers (De Raedt & Ponjaert-Kristoffersen, 2000), while Lundberg et al. (1998) showed that poorer visuospatial memory was associated with crash involvement.

In contrast, spatial memory and driving attitudes and behaviour were not related. Specifically, spatial memory was not related to perceived driving ability, confidence in difficult driving situations, or avoidance of these situations. Therefore, poorer spatial memory is related to poorer driving ability among older drivers but is not associated with self-regulation of driving. This means that those older drivers with deficits in visuospatial memory may be a group whose self-regulation of driving is inadequate to compensate for their poorer driving ability.

11.4.8 Visual Attention

Visual attention was found to be very important for the ability to drive: all reaction time scores and two of the detection error scores on the CVAT shared moderate relationships with driving ability. Furthermore, two of the four variables that made independent contributions to the prediction of driving ability were visual attention measures. These were both measures of reaction time to stimuli in the peripheral visual field, with one measure assessing selective and divided attention, and the other assessing simple attention. This emphasises the importance for driving of being able to quickly detect stimuli in the visual periphery. The importance of visual attention for driving ability has been reported previously in studies of older drivers (e.g. Clark et al., 2000; De Raedt & Ponjaert-Kristoffersen, 2000; Hunt et al., 1993; Richardson & Marottoli, 2003).

Visual attention was also related to driving attitudes and behaviour. Although CVAT measures were unrelated to perceived driving ability, two of the reaction time scores and one of the detection error scores were related to confidence in difficult driving situations. Two of these scores were for the CVAT task requiring selective and divided attention to stimuli in the peripheral visual field, which was the most complex task on the CVAT. The other was a measure of simple attention to stimuli in the peripheral visual field. The results for avoidance of difficult driving situations were similar to those for confidence, with avoidance being related to two reaction time scores and one detection error score. Once again, two scores came from the CVAT task that assesses selective and divided attention to stimuli in the peripheral visual field, and the other score came from a task that assesses simple attention to peripheral stimuli. Furthermore, two of the four best predictors of avoidance of difficult driving situations were visual attention measures: detection errors for the task requiring selective and divided attention to stimuli in the peripheral visual field, and reaction times for the task requiring simple attention to stimuli in the peripheral visual field. These results are consistent with previous findings of a relationship between visual attention and self-regulation (Ball et al., 1998; Hennessy, 1995).

Therefore, the relationship between visual attention and driving ability was similar to that between visual attention and driving behaviour. Both driving ability and self-regulation were best predicted by measures of selective and divided attention for stimuli in the peripheral visual field, and by a measure of simple attention for peripheral stimuli. This suggests that the declines in attention that are related to deficits in driving ability among older drivers are also associated with self-regulation of driving. The possibility that older drivers are able to detect and respond to deficits in attention is further suggested by a moderate relationship between *perceived* dual task ability and a measure of *actual* dual task ability (an index of divided attention). Perceived dual task ability was also related to on-road driving ability, confidence in difficult driving situations, and avoidance of these situations. This may mean that older drivers detect declines in their ability to attend to multiple stimuli when driving, lose confidence in difficult driving situations, and respond with self-regulation. Such a causal sequence, however, must remain conjectural and it must also be noted that the relationships between attention and driving ability were slightly larger (mostly moderate) than those between attention and avoidance of difficult driving situations (mostly small). Therefore, although the results suggest a promising relationship between declines in attention and alteration of driving behaviour by older adults, this relationship may not be optimal.

11.4.9 Summary

The functional measures used in the present study can be categorised according to their relationships with driving ability and self-regulation. If a measure was related to both driving ability and self-regulation, then this suggests that deficits in that type of functioning are associated with appropriate self-regulation. If a measure shared a relationship with driving ability but not with self-regulation, then that suggests that older adults with deficits in that type of functioning may be a group who restrict their driving less than they should. If a measure was associated with self-regulation but not with driving ability, then older adults with deficits in that type of functioning may be a group who restrict their driving more than is necessary. If a measure was related to neither self-regulation nor driving ability, then it is not relevant to the issue of self-regulation.

Functional abilities related to both driving ability and self-regulation included vision measures and visual attention, suggesting that drivers with worse vision or visual attention had deficits in their driving ability but were more likely to avoid difficult driving situations. However, these conclusions need to be qualified. Although vision was related to both driving ability and self-regulation, driving ability was more closely related to contrast sensitivity, while self-regulation was more closely related to visual acuity. Therefore, although vision was indeed related to driving ability and older adults with deficits in vision did restrict their driving, these restrictions to driving were not associated with the specific aspect of vision that would have produced appropriate self-regulation. With regard to visual attention, driving ability and self-regulation were both most closely related to divided and selective attention for stimuli in the peripheral visual field but the association was stronger for driving ability, suggesting that the association between self-regulation and visual attention was not optimal.

Functional measures that were related to neither driving ability nor self-regulation included an index of physical functioning (neck mobility), mood-related factors (depressed mood and anxiety) and mental status, suggesting that these functional measures are not relevant to the issue of older driver self-regulation. However, non-significant trends for the relationships between worse driving ability and higher depressed mood scores, and between greater self-regulation and an anxious disposition (trait anxiety) suggest the need for a study specifically designed to examine the self-regulation of older adults with a broader range of scores on indices of anxiety and depressed mood. In regard to mental status, the lack of a significant relationship with on-road driving ability may be due to the use of a largely healthy, community-dwelling sample rather than one featuring a high representation of drivers with cognitive impairment. Given previous research findings relating cognitive impairment to poorer on-road driving ability but not greater self-regulation, drivers with mental status scores suggestive of impairment would be a candidate group for interventions promoting restrictions of driving behaviour.

Visual acuity (as noted above) and health measures (general health and medication use) were more closely related to self-regulation than driving ability. Although the latter finding suggests the possibility that older adults restrict their driving too much in response to medical conditions, it must be borne in mind that the medical conditions examined here, and their associated symptoms, may be easier for older adults to detect and respond to than the declines in functional abilities most closely related to driving ability. As declines in health are often associated with declines in functioning, self-regulation in response to declining health may be a useful proxy for self-regulation in response to declining functional abilities.

There were three functional measures that were related to driving ability but not to self-regulation, indicating that poor results on these measures may identify drivers who are likely to have driving difficulties but not respond to them by restricting their driving. These measures were contrast sensitivity, speed of information processing, and spatial memory. Therefore, drivers with poor contrast sensitivity (but adequate visual acuity), slowed information processing and poorer spatial memory would be good candidates for any educative interventions aiming to encourage self-regulation of driving.

11.5 Overall Conclusions

This thesis was concerned with the self-regulation of driving behaviour by older adults in South Australia. The investigation of self-regulation involved a background study of the crash involvement of older drivers in South Australia across a five year period; a survey of driving attitudes and behaviour among a sample of drivers aged 60 or more; and an examination of the relationship between driving attitudes and behaviour, and performance on tests of functioning and driving ability. One of the main strengths of the study was that actual on-road driving ability was compared with driving behaviour, which had been done very rarely in previous older driver research, and never before using a sample of generally healthy adults aged over 60. In addition, the measurement of various types of functioning (mood-related, physical functioning, vision, mental status, speed of information processing, spatial memory, visual attention) for the same set of participants enabled comparisons between the variables that are most related to driving ability and the variables most related to driving behaviour. These comparisons, in turn, enabled the identification of the functional variables that are related to driving deficits but for which drivers are not adequately compensating. Such an analysis had not previously been conducted in older driver research.

The analysis of crash statistics over a five year period confirmed that South Australian older drivers are typical of those in other jurisdictions. Their level of crash involvement is only higher than drivers in younger age groups when expressed in terms of crashes per kilometre driven. There was some evidence in the crash data of self-regulation, with older drivers being less likely to crash in peak hour traffic, in hours of darkness, in the rain, or on wet roads. The remainder of the thesis was designed to examine the self-regulatory driving practices of older drivers in more depth.

The picture that emerged from the survey of driving attitudes and behaviour used in this study was that community-dwelling active older drivers tend to be confident in their driving abilities and chiefly restrict their driving in response to reductions in the *need* to drive (e.g. retirement). Maintenance of lifestyle was reported as being very important for the drivers in the study and restriction of driving tended to only occur to the extent that their lifestyles allowed for it. As future cohorts of older drivers are likely to be increasingly active (OECD, 2001), it is likely that the desire to maintain lifestyle will continue to reduce self-regulation of driving.

Older drivers also reported positive self-assessments of their abilities (driving, vision, dual task), high confidence when driving in difficult situations, and little avoidance of these situations. A new finding was that the relationship between confidence in a specific driving situation and avoidance of that specific situation was stronger for situations that older drivers found easier to avoid. That is, how easy it is to avoid a specific difficult driving situation was related to the degree to which lower confidence when driving in that situation was translated into avoidance of the situation.

Of concern was the rarity with which older drivers reported avoidance of right turns across traffic, despite the finding that right turn crashes, especially when as the driver of the turning vehicle, are common among older drivers. This rarity of avoidance of right turn crashes does not appear to be due to difficulty avoiding them, as nearly half of the sample reported right turns as not hard to avoid - only parallel parking and peak hour were more likely to be designated as not hard to avoid. Any program designed to encourage older driver self-regulation should include discussions of right turns across traffic.

As noted earlier, one of the main strengths of the study was the use of a measure of on-road driving performance in order to analyse the relationships between driving attitudes and behaviour, and driving ability. One of the interesting findings from these analyses was that *actual* on-road driving ability was unrelated to *perceived* driving ability but was related to perceived *dual task* ability. This suggests that older drivers detect declines in the dual task aspects of driving prior to detecting any overall deficits in driving ability. Furthermore, it suggests that an older adult's self-assessment of their ability to carry out simultaneous tasks may give a better indication of his or her driving ability than a self-assessment of driving ability. The usefulness of *perceived* dual task ability as a measure is also illustrated by its relationship with *actual* dual task ability, as measured by an index of divided attention. Therefore, there appears to be a degree of accuracy to perceived dual task ability that is lacking in perceived driving ability and perceived vision (found to be unrelated to performance on vision tests).

Another finding of interest was that, although there were no relationships between driving ability and *overall* confidence in, or avoidance of, difficult driving situations, this concealed relationships between driving ability and confidence in, and avoidance of, *specific* driving situations. Poorer on-road driving ability was associated with lower confidence in, and greater avoidance of, driving in the rain, driving at night, and driving at night in the rain. Therefore, it is possible that these are situations in which older drivers most notice declines in driving ability, and respond to these declines with avoidance.

As noted earlier, another of the strengths of the study was that it enabled a comparison of the relationships between functional measures and both driving ability and self-regulation. It was found that driving ability was better predicted by functional measures than was self-regulation. When the various functional measures were examined separately, in order to determine which of these measures might best identify drivers least likely to be self-regulating in accordance with their abilities, the variables that were found to be related to driving ability but not self-regulation were contrast sensitivity, speed of information processing, and spatial memory. This suggests that older drivers with low scores on tests of these abilities may be appropriate targets for interventions designed to encourage self-regulation. Two of these measures, contrast sensitivity and spatial memory, were among the best predictors of driving ability, and their limited relationship with self-regulation suggests that they may also be useful as part of re-licensing assessments. Contrast sensitivity, in particular, would be preferable in re-licensing assessments to the more typically assessed visual acuity, which was not found to be related to driving ability in the sample of participants assessed in this study.

The measure of visual attention developed for the study, the Computerised Visual Attention Test, was found to be related to both driving ability and self-regulation. Of all the functional measures, it was the best predictor of performance on the driving test, making it a useful measure for driver re-licensing assessments. In addition, the length of time required for test administration could be greatly reduced by only using the subtest assessing both selective and divided attention. Measures from this subtest were found to be the best predictors of both driving ability and avoidance of difficult driving situations. The use of only this subtest would reduce the time of administration to approximately 15 minutes, including test demonstration and practice, rather than approximately 35 minutes for the full test. However, the CVAT does need further validation. Specifically, its predictive validity has not been established among samples of impaired drivers and its predictive validity for prospective crash involvement has yet to be assessed. Moreover, to be a candidate for re-licensing assessments, its predictive validity would need to be compared with that of other tests of attention, such as the UFOV. If the CVAT is found to have predictive validity that is superior or comparable to the UFOV, then the CVAT may be a good alternative to it. The CVAT, unlike the UFOV, does not require special, expensive equipment and does not require that test takers sit uncomfortably close to the computer screen.

Having established that self-regulation among older drivers is not optimal, it may be useful to consider implementation of a program to encourage self-regulation. One such program has already been reported in the literature. Owsley, Stalvey and Phillips (2003) examined an educational intervention in the USA in which older drivers with visual impairment who had crashed in the previous year were informed about how visual impairment affects driving. The participants were also given advice about reducing driving through the avoidance of difficult driving situations. Following this intervention, drivers were more likely to acknowledge their visual impairments and were more likely to avoid difficult situations (Owsley et al., 2003). It is possible, however, given the use of self-reports of behaviour as an outcome measure after the intervention, that these results were affected by response bias, with participants reporting the behaviour changes the intervention was advocating. The authors indicated that the safety benefits of the program will be evaluated.

Any implementation of programs designed to encourage self-regulation would ideally be combined with a service providing assessments of driving ability. There was no relationship between *perceived* driving ability and *actual* on-road driving ability, and it would be useful if drivers of all ages could refer themselves for a driving assessment and get objective feedback from appropriately qualified personnel about their driving (Stutts, 2003). This feedback could be combined with a discussion about methods of self-regulating driving, in cases where it was felt by the driving assessors to be useful. Such programs would have to be undertaken with a great deal of care, however, as Holland and Rabbitt (1992) found that giving older drivers feedback about their sensory abilities and self-regulation caused a small number of participants to experience anxiety.

11.6 Limitations and Future Directions

Previous chapters have made reference to various limitations of the present study. These have included the lack of validation of the measure of driving ability, the measures of driving confidence and driving avoidance being based on questions regarding driving situations that were not assessed in the driving test, the self-reported nature of the health measures and the measures of driving attitudes and behaviour, and the possibility of volunteer bias.

The absence of validation data for the on-road driving test means that it has not been shown that this measure is related to routine driving performance when a driver is not being assessed, or to actual crash risk. It could be that the validity of the driving test is reduced by being conducted in an unfamiliar car and, for many drivers, on streets that they did not normally drive on. However, the driving tests used in the study were very detailed and used the expertise of both occupational therapists and professional driving instructors. Also, the alternative of using crash involvement as an indicator of deficits in driving ability is problematic because crashes are rare, multi-determined events (refer to section 8.4.2). Nonetheless, the access to participants' official records means that their crash involvement can be monitored and the relationship between driving performance, as assessed in this study, and subsequent crash risk examined in the future. This will be an important ongoing part of establishing the validity of the conclusions of this study because claims that self-regulation is less than optimal, based on the lack of strong relationships between self-regulation and driving test performance, rely on driving test performance being predictive of crash risk.

Another study limitation related to the on-road driving test is that the test did not assess driving performance in many of the situations that were the focus of the questions concerning driving confidence and driving avoidance. The on-road assessment did not require participants to drive in the rain, when alone, on freeways, at peak hour, at night, or at night in the rain. It also did not assess reverse parallel parking. It is likely that the driving performance scores of participants who often avoided difficult driving situations would have been poorer if their driving was assessed in these situations. Therefore, the likely result of this limitation of the driving test is that the relationships reported in this study are under-estimates of the true relationships between driving ability and self-regulation. However, the driving tests did assess performance in a variety of traffic conditions, ranging from quiet streets to busy main roads and, as noted by Lundberg et al. (1997, p34), it would be inappropriate to test the driving ability of older drivers in situations they usually avoid.

With respect to using self-reported measures of a number of variables, it is possible that the information derived from these measures was not accurate. Specifically, there could be inaccuracies in the number of medical conditions and medications reported by study participants, and in reports of the weekly amounts of driving done, and recent crash involvement and traffic violations. Inaccuracies in estimates of weekly driving done are likely to be random but omissions of crashes or medical conditions in self-reports could have been either accidental or deliberate. Of these self-reported measures, only crash involvement could be checked against official records in this study and, indeed, it was found that some participant self-reports omitted reference to recent crashes. Participants may also have tried to give a 'good' or socially desirable account of themselves, reporting high driving confidence and driving ability, and low driving avoidance. This may have affected the analyses of relationships between these measures and on-road driving ability.

Finally, volunteer bias could have affected the results because older drivers volunteering for a study that included an on-road driving assessment, for which poor results would be reported to the participant's general practitioner, could have been more likely than the average older driver to be confident about their driving ability. If this was the case, the participants in the study who had deficits in their driving ability would have been more likely to have been those who were unaware of these deficits. This, in turn, would have reduced the relationships between on-road driving ability and perceived driving ability, driving confidence and driving avoidance, leading, again, to an under-estimation of the strength of the real relationships. As noted by Lee et al. (2003), the problem of volunteer bias in driving studies involving healthy participants is unavoidable.

The study also points to a number of avenues of future research. One is an investigation of the means by which to obtain better travel distance data than are currently available in Australia. The Australian Bureau of Statistics Travel Surveys are vehicle-based rather than driver-based and so are unsuited to analysis of crash rates for drivers of different ages. One possible method of obtaining useful travel data is recruiting a large sample of drivers to fill in detailed travel diaries.

Another avenue of future research is investigation into the relationships between medical conditions, use of medications, driver age and driving ability. The separation of the effects of medical conditions from those of the medications taken to treat them is difficult but a study using carefully chosen control groups matched for illness severity may prove informative. Also, it would be useful for such a study to utilise official medical records rather than self-reported information.

It would also be interesting to see if the results of the present study can be repeated in a prospective study using future crash involvement, rather than on-road driving performance, as an outcome measure. Specifically, it could be ascertained whether performance on the Computerised Visual Attention Test predicts future crash involvement better than other functional variables. As noted previously, access to participants' official records will enable a prospective study of participant crash involvement. Such a prospective study is also necessary to evaluate the relationships between future crash involvement, and driving confidence and driving avoidance. The use of retrospective crash data is not ideal because past crashes could affect currently reported confidence in, and avoidance of, difficult driving situations. It needs to be assessed whether currently reported confidence and avoidance are related to levels of future crash involvement. The conclusion that self-regulation may need to be encouraged among older drivers relies on self-regulation being linked with lower subsequent crash risk.

Future research should also look at the personality and lifestyle factors that play a role in self-regulation. There was a substantial proportion of variance in self-regulation unexplained by the functional measures used in the present study and it may be that personality traits (e.g. conscientiousness) and lifestyle factors (e.g. extent of social activities) could account for some of this variance in self-regulatory behaviour. One study looking at driving attitudes and personality found that high confidence in difficult driving situations among drivers aged over 50 was associated with low neuroticism and high extroversion (Parker et al., 2001).

A final suggestion for future research is to look at the driving ability and behaviour of drivers with depression and high anxiety. It appears that these two mood-related factors may have very different effects on driving-related measures. A study designed to look specifically at such drivers would help clarify the results of the present study.

11.7 Final Conclusion

Overall, the present study has demonstrated that older drivers do engage in a degree of self-regulation of driving behaviour, and that this self-regulation does have a relationship with driving ability. However, the relationship between self-regulation and driving ability was not strong, suggesting that many older adults with deficits in their driving ability do not avoid difficult driving situations. One of the strengths of the study was that it made it possible to identify the factors that may decrease the likelihood of older drivers self-regulating in accordance with their abilities. These findings could be used to guide re-licensing assessments and educative interventions designed to encourage self-regulation, both of which may be of importance in years to come, as the number of older drivers on Australian roads increases. These increases in the number of older drivers will occur in combination with cohort differences that will give rise to better health and greater driving experience among future older drivers than was the case for earlier cohorts. It may be that these cohort differences will result in a lower need for self-regulation of driving behaviour. It could also be that a greater dependence on driving throughout the lifespan may result in less acceptance of the need to alter driving behaviour if necessary (Rosenbloom, 2003) and, thus, a lessening of the relationships between self-regulation and the deficits in functional and driving abilities that would ideally prompt it. Therefore, continuing research will be needed to follow the changing trends in the abilities, behaviour and crash experience of older drivers, and to shape transport policies relating to their safety and mobility.

APPENDICES

APPENDIX 2A

TARS DATABASE CODING

CRASH

Report Number: 001-008

Road Number 1: 009-016

Road Number 2: 017-024

LGA: 063-065
XXX=unknown

Statistical Area: 069-071
001=city
002=metropolitan
003=country
XXX=unknown

Total Units: 072-073
XX=99

Total Casualties: 074-075
XX=99

Date of Crash: 079-097

Time of Crash: 098-116

Day of Week: 117-117
1=Monday
2=Tuesday
3=Wednesday
4=Thursday
5=Friday
6=Saturday
7=Sunday
X=unknown

Speed Limit: 118-120
XXX=999

Damage Estimate: 121-131

Intersection Type: 132-132
1=interchange
2=cross road
3=y-junction

4=t-junction
5=multiple
6=rail xing
7=other
N=not intersection

Nonintersection Type: 133-134
01=crossover
02=rail crossing
03=divided road
04=not divided
05=one way
06=freeway
07=ramp on
08=ramp off
09=pedestrian crossing
10=other
N =not applicable

Road Surface: 136-136
1=sealed
2=unsealed
X=unknown

Road Wetness: 137-137
1=wet
2=dry
X=unknown

Weather Conditions: 138-138
1=raining
2=not raining
X=unknown

Lighting Conditions: 139-139
1=daylight
2=dawn or dusk
3=night
X=unknown

Crash Type: 140-141
01=rear end
02=hit fixed object
03=side swipe
04=right angle
05=head on
06=hit pedestrian
07=roll over
08=right turn
09=hit parked vehicle
10=hit animal
11=hit object on road

12=left road out of control
13=other
14=unknown
XX=unknown

Unit Responsible: 142-143
XX=unknown

Entity Responsible: 144-144
1=driver rider
2=passenger
3=pedestrian
4=animal
5=other
6=none
X=unknown

Accident Severity: 145-145
1=property
2=injury
3=fatal
X=unknown

Traffic Control: 146-147
01=traffic signals
02=rail boom
03=rail flashing
04=rail none
05=stop sign
06=give way
07=none
08=roundabout
09=other
XX=unknown

Crash Postcode: 171-174
XXXX=9999

Road Vertical Alignment: 175-175
4=level
5=crest of hill
6=bottom of hill
7=slope
X=unknown

Other Road Features: 176-177
08=bridge culvert causeway
09=roadworks
10=driveway or entrance
11=road hump or slow point
12=median opening
13=none

XX=unknown

UNIT

Report Number: 001-008

Unit Number: 009-010

Unit Casualties: 011-012

Unit Registration: 013-018
XXXXXX=unknown

Unit State Registration: 019-019
1=NSW
2=VIC
3=QLD
4=SA
5=WA
6=TAS
7=NT
8=ACT
9=overseas
X=unknown

Unit Type: 020-021
01=car sedan
02=car tourer
03=station wagon
04=panel van
05=utility
06=taxi
07=truck
08=semi
09=omnibus
10=other defined
11=other unknown
12=motorcycle
13=tree
14=traffic signal pole
16=animal wild
17=pedal cycle
18=animal drawn vehicle
19=ridden animal
21=pedestrian on road
22=bridge
23=sign post
24=stobie pole (utility pole)
25=other fixed obstruction
26=animal domestic
27=railway vehicle

28=tram
29=other
32=small wheel vehicle
30=forward control van
31=guard rail
15=pole
20=pedestrian in car park
XX=unknown

Unit Make: 022-023

Unit Year: 024-025
XX=unknown

Unit Direction: 026-026
1=N
2=NE
3=E
4=SE
5=S
6=SW
7=W
8=NW
X=unknown
N=NA

Driver Sex: 027-027
1=male
2=female
X=unknown

Driver Age: 028-029
XX=99

Licence Number: 030-039 (-035)
XXXXXXXXXX=unknown

Licence State: 040-040
1=NSW
2=VIC
3=QLD
4=SA
5=WA
6=TAS
7=NT
8=ACT
9=OS
X=unknown

Licence Type: 044-044
1=learners
2=provisional

3=full
4=unlicenced
X=unknown

Unit Towing: 049-049
1=trailer
2=caravan
3=boat
4=horse float
5=agricultural implement
6=motor vehicle
7=other
8=not towing
X=unknown

Vehicle Movement: 051-052
01=right turn
02=left turn
03=u turn
04=swerving
05=reversing
06=stopped on road
07=straight ahead
08=entering driveway
09=leaving driveway
10=parked
11=parking angle
12=parking parallel
13=unparking angle
14=unparking parallel
15=overtaking on right
16=overtaking on left
17=other
XX=unknown

Pedestrian Movement: 053-054
01=walk on footpath
02=on ped crosssing
03=within 30m ped xing
04=from parked vehicle
05=between parked vehicles
06=walking on road
07=on road against traffic
08=pushing/working on vehicle
09=playing on road
10=crossing without control
11=other
12=crossing with traffic signals
XX=unknown

Apparent Error: 055-056
01=excessive speed

02=fail to stand
03=fail to keep left
04=changed lanes to endanger
05=fail to give way right
06=incorrect turn
07=reverse without due care
08=follow too closely
09=overtake without due care
10=disobey traffic lights
11=disobey stop sign
12=disobey give way sign
13=disobey police signal
14=disobey railway signal
15=incorrect or no signal
16=inattention
17=no errors
18=other
19=dangerous driving
20=DUI (driving under the influence of alcohol or a drug)
21=misjudgement
22=vehicle fault
23=insecure load
24=died/sick/asleep
25=opening or closing door
26=drunken pedestrian
27=brake failure
28=broken windscreen
29=fail to give way
XX=unknown

Driver BAC: 059-061

067-070 postcode
071-073 speed before impact

CASUALTY

Report Number: 001-008

Casualty Unit Number: 009-010

Casualty Number: 011-012

Casualty Type: 013-013
1=driver
2=rider
3=passenger
4=pedestrian
X=unknown

Casualty Sex: 014-014

1=male
2=female
X=unknown

Casualty Age: 015-016
XX=99

Casualty Position: 021-022
01=driver
02=front seat middle passenger
03=front seat left passenger
04=right seat right passenger
05=right seat middle passenger
06=right seat left passenger
07=nursed front
08=nursed back
09=back open tray
10=back closed van
11=passenger in multiseat vehicle
12=MC Rider
13=MC Pillion
14=occupant of a vehicle being towed
15=other
XX=unknown

Casualty Ejection: 023-023
1=ejection
2=no ejection
X=unknown

Injury Nature: 024-024
1=head
2=chest/body
3=multiple
4=internal
5=shock
6=limbs
7=neck
8=other
X=unknown

Injury Extent: 025-025
1=not treated
2=private doctor
3=hospital treated
4=hospital admitted
5=fatal

Seatbelt Use: 026-026
1=fitted worn
2=fitted not worn
3=child restraint worn

4=child restraint not worn
5=fitted unknown worn
6=not fitted
7=NA
X=unknown

Helmet Worn: 027-027
1=worn
2=not worn
3=NA
X=unknown

Casualty Hospital: 028-033

APPENDIX 2B

Table 1
Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group

Age Group	Percentage of Population
16-24	39.8
25-34	26.2
35-44	22.0
45-54	18.9
55-64	15.2
65-74	12.7
75-84	10.7
85+	4.8
Total	22.5

Table 2
Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged Over 84

	Ratio to Drivers Aged Over 84 by Crash Injury Severity				
Age Group	PDO	Private Doc	Hosp Treat	Hosp Admit	Fatal
16-24	8.5	11.6	6.9	5.9	2.9
25-34	5.6	8.3	4.1	3.4	1.7
35-44	4.8	7.3	3.2	2.3	1.2
45-54	4.2	6.1	2.5	2.0	0.8
55-64	3.4	4.1	2.0	1.8	1.0
65-74	2.8	2.8	1.7	1.7	1.1
75-84	2.3	2.1	1.8	1.8	1.4
85+	1.0	1.0	1.0	1.0	1.0

Note. PDO = Property Damage Only; Private Doc = Treated by a Private Doctor; Hosp Treat = Treated at Hospital; Hosp Admit = Admitted to Hospital

Table 3
Crash-Involved Drivers Per Licensed Driver in South Australia from 1994 to 1998, by Age Group

Age Group	Percentage of Drivers
16-24	57.0
25-34	32.6
35-44	28.3
45-54	24.2
55-64	21.5
65-74	20.9
75-84	18.7
85+	19.6
Total	31.0

Table 4

Crash-Involved Drivers Per Licensed Driver in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 75 to 84

	Ratio to Drivers Aged 55 to 64 by Crash Injury Severity				
Age Group	PDO	Private Doc	Hosp Treat	Hosp Admit	Fatal
16-24	3.0	4.5	3.1	2.7	1.6
25-34	1.7	2.8	1.6	1.4	0.8
35-44	1.5	2.6	1.3	1.0	0.6
45-54	1.3	2.1	1.0	0.8	0.4
55-64	1.2	1.6	0.9	0.8	0.5
65-74	1.1	1.3	0.9	0.9	0.7
75-84	1.0	1.0	1.0	1.0	1.0
85+	1.0	1.1	1.3	1.3	1.6

Note. PDO = Property Damage Only; Private Doc = Treated by a Private Doctor; Hosp Treat = Treated at Hospital; Hosp Admit = Admitted to Hospital

Table 5

Average Kilometres Driven (÷ 1,000) by Drivers in South Australia in the 12 Months, 1997-1998, by Age Group

Age Group	1,000 Kilometres Driven	Relative Standard Error (%)*
16-24	6.3	26
25-34	11.8	20
35-44	8.7	9
45-54	9.4	15
55-64	8.4	12
65-74	8.4	23
75-84	3.6	27
85+	0.0	0
Unknown	14.9	47
Total	9.2	7

* The Relative Standard Error is the standard error of the estimate expressed as a percentage of the estimate. It shows the percentage error likely to have occurred by sampling.

Table 6

Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group

Age Group	Crash-Involved Drivers per Million Km Driven
16-24	15.0
25-34	4.2
35-44	4.3
45-54	3.3
55-64	3.5
65-74	3.8
75-84	9.9
Total	6.2

Table 7

Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 45 to 54

	Ratio to Drivers Aged 45 to 54 by Crash Injury Severity				
Age Group	PDO	Private Doc	Hosp Treat	Hosp Admit	Fatal
16-24	4.4	4.0	5.8	6.1	7.5
25-34	1.2	1.2	1.5	1.5	1.9
35-44	1.3	1.3	1.4	1.2	1.6
45-54	1.0	1.0	1.0	1.0	1.0
55-64	1.1	0.9	1.0	1.1	1.6
65-74	1.2	0.8	1.2	1.4	2.2
75-84	3.0	1.8	3.8	4.5	9.4

Note. PDO = Property Damage Only; Private Doc = Treated by a Private Doctor; Hosp Treat = Treated at Hospital; Hosp Admit = Admitted to Hospital

Table 8

Crash-Involved Drivers Whose Crashes Resulted in a Serious or Fatal Injury to One or More Crash Participants in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	3.3	3.1-3.5
25-34	3.0	2.8-3.2
35-44	2.4	2.2-2.6
45-54	2.4	2.2-2.6
55-64	2.7	2.4-3.0
65-74	3.1	2.7-3.5
75-84	4.0	3.4-4.6
85+	5.2	3.3-7.1
Unknown	0.6	0.5-0.7
Total	2.4	2.3-2.5

Table 9

Crash-Involved Drivers Who Were Seriously Injured (Admitted to Hospital or Killed) in the Crash in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	1.6	1.5-1.7
25-34	1.3	1.2-1.4
35-44	1.0	0.9-1.1
45-54	1.1	1.0-1.2
55-64	1.4	1.2-1.6
65-74	1.7	1.4-2.0
75-84	2.5	2.0-3.0
85+	3.8	2.2-5.4
Unknown	0.1	1.0-1.0
Total	1.1	1.1-1.1

Table 10

Crash-Involved Drivers Who Crashed at an Intersection in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	% Crashes at an Intersection	99 % Confidence Intervals
16-24	54.1	53.6 - 54.6
25-34	54.6	54.1 - 55.1
35-44	54.4	53.8 - 55.0
45-54	54.6	53.9 - 55.3
55-64	55.4	54.5 - 56.3
65-74	54.4	53.4 - 55.4
75-84	55.6	54.1 - 57.1
85+	55.2	51.0 - 59.4
Unknown	40.6	40.1 - 41.1
Total	51.5	51.3 - 51.7

Table 11

Crash-Involved Drivers Who Were Involved in a Right Turn Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	7.7	7.4-8.0
25-34	6.4	6.1-6.7
35-44	5.7	5.4-6.0
45-54	5.9	5.6-6.2
55-64	6.2	5.8-6.6
65-74	7.0	6.5-7.5
75-84	8.1	7.3-8.9
85+	9.8	7.3-12.3
Unknown	1.9	1.8-2.0
Total	5.6	5.5-5.7

Table 12

Crash-Involved Drivers Who Were Turning Prior to the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	13.3	13.0-13.6
25-34	10.0	9.7-10.3
35-44	10.1	9.8-10.4
45-54	10.6	10.2-11.0
55-64	12.3	11.7-12.9
65-74	16.8	16.0-17.6
75-84	21.7	20.5-22.9
85+	26.4	22.7-30.1
Unknown	7.3	7.0-7.6
Total	11.0	10.9-11.1

Table 13

Right Turn Crash-Involved Drivers Who Were Turning Right at the Time of the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	49.8	48.1-51.5
25-34	39.6	37.5-41.7
35-44	43.7	41.3-46.1
45-54	46.0	43.2-48.8
55-64	50.8	47.1-54.5
65-74	62.1	58.3-65.9
75-84	75.9	71.4-80.4
85+	83.7	73.8-93.6
Unknown	62.8	59.4-66.2
Total	49.1	48.2-50.0

Table 14

Crash-Involved Drivers Who Disobeyed a Traffic Signal, Stop Sign or Give Way Sign in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	2.8	2.6-3.0
25-34	2.3	2.1-2.5
35-44	2.3	2.1-2.5
45-54	2.9	2.7-3.1
55-64	3.9	3.5-4.3
65-74	6.0	5.5-6.5
75-84	8.6	7.8-9.4
85+	11.4	8.7-14.1
Unknown	1.7	1.6-1.8
Total	2.8	2.7-2.9

Table 15

Crash-Involved Drivers Deemed to be Responsible for the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	55.3	54.8-55.8
25-34	45.0	44.5-45.5
35-44	42.0	41.4-42.6
45-54	41.2	40.5-41.9
55-64	45.0	44.1-45.9
65-74	55.8	54.8-56.8
75-84	67.6	66.2-69.0
85+	80.9	77.6-84.2
Unknown	52.9	52.4-53.4
Total	49.2	49.0-49.4

Table 16

Crash-Involved Drivers Deemed to Have Been Driving at Excessive Speed in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	1.5	1.4-1.6
25-34	0.6	0.5-0.7
35-44	0.3	0.2-0.4
45-54	0.2	0.1-0.3
55-64	0.1	0.0-0.2
65-74	0.1	0.0-0.2
75-84	0.2	0.1-0.3
85+	0.2	0.0-0.6
Unknown	0.3	0.2-0.4
Total	0.6	0.6-0.6

Table 17

Percentage of Crash-Involved Drivers for Whom a Blood Alcohol Concentration was Known and Whose Crashes Produced a Serious Injury for One or More Crash Participants in South Australia 1994 to 1998, by Age Group

Age Group	BAC Known	Serious Injury Crashes
16-24	5.5	3.3
25-34	4.4	3.0
35-44	3.6	2.3
45-54	3.5	2.4
55-64	3.7	2.7
65-74	4.3	3.1
75-84	6.1	4.0
85+	8.6	5.3
Unknown	0.2	0.6
Total	3.5	2.4

Table 18

Crash-Involved Drivers with a Blood Alcohol Concentration over 0.05 g/L in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	14.0	13.7-14.3
25-34	18.2	17.8-18.6
35-44	12.0	11.6-12.4
45-54	8.1	7.7-8.5
55-64	6.7	6.2-7.2
65-74	3.4	3.0-3.8
75-84	2.0	1.6-2.4
85+	0.0	0.0-0.0
Unknown	19.0	18.6-19.4
Total	12.4	12.3-12.5

Table 19

Crash-Involved Drivers Who Crashed During Peak Traffic Times in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	27.6	27.2-28.0
25-34	28.7	28.2-29.2
35-44	29.1	28.6-29.6
45-54	28.9	28.3-29.5
55-64	23.3	22.5-24.1
65-74	17.0	16.2-17.8
75-84	13.4	12.4-14.4
85+	11.8	9.1-14.5
Unknown	24.3	23.9-24.7
Total	26.3	26.1-26.5

Table 20

Crash-Involved Drivers Who Crashed During Daylight in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	73.1	77.4-78.6
25-34	80.6	84.9-86.1
35-44	84.4	87.0-88.2
45-54	85.5	87.0-88.4
55-64	88.6	89.9-91.7
65-74	91.4	92.7-94.5
75-84	93.4	93.7-95.9
85+	95.4	94.3-99.7
Unknown	81.1	88.3-89.7
Total	81.4	85.4-86.0

Table 21

Crash-Involved Drivers Who Crashed on Wet Roads in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	15.9	15.6-16.2
25-34	14.5	14.1-14.9
35-44	13.9	13.5-14.3
45-54	13.4	12.9-13.9
55-64	12.0	11.4-12.6
65-74	10.5	9.9-11.1
75-84	9.6	8.7-10.5
85+	7.8	5.5-10.1
Unknown	11.3	11.0-11.6
Total	13.4	13.2-13.6

Table 22

Crash-Involved Drivers Who Crashed During Rain in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

Age Group	Percentage of Drivers	Confidence Intervals
16-24	10.5	10.2-10.8
25-34	9.7	9.4-10.0
35-44	9.2	8.9-9.5
45-54	9.2	8.8-9.6
55-64	8.3	7.8-8.8
65-74	7.3	6.8-7.8
75-84	6.8	6.0-7.6
85+	4.7	2.9-6.5
Unknown	7.5	7.2-7.8
Total	9.0	8.9-9.1

APPENDIX 5A

THE SELF-REGULATION OF DRIIVNG BEHAVIOUR

PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF ADELAIDE AUSTRALIA

MATTHEW BALDOCK
ROAD ACCIDENT RESEARCH UNIT
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5887

DR JANE MATHIAS
DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5266

PILOT STUDY

The Psychology Department and Road Accident Research Unit of Adelaide University are conducting a study into the "self regulation" of driving behaviour among senior drivers. The study has been designed to see if senior drivers adjust their driving habits and if so, how. The study will be useful for identifying what makes some senior drivers alter their driving habits and also whether doing so provides any safety benefits to these drivers. Before the study can commence, so-called "pilot testing" of the measures to be used in the full study is required. This involves testing a small number of volunteers and is done to ensure the practicality of the measures to be used.

If you choose to volunteer for the study, you will be asked to aid the researchers in the following ways:

1) By completing in your own time a small number of questionnaires about driving habits prior to your assessment and medical conditions you might have. These will be posted to you and should take no more than 30 minutes.

2) By attending the Road Accident Research Unit (Medical School South, Adelaide University) for an individual session of no more than 2 hours, in which you will be asked to complete a few tests of vision and thinking skills.

The study is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage. All information gathered in the study will be kept completely confidential. Only group statistics will be reported in any publications that result from the study. Travel to and from the University will be paid for with Cabcharge vouchers and you will be reimbursed for your time with a payment of $25.

Your written consent to participate in all aspects of the study will be sought before you start. This study has been approved by the Ethics Committee of the Department of Psychology, Adelaide University and that of the University of South Australia. If you have any concerns or wish to discuss the study you may contact Matthew Baldock at the Road Accident Research Unit or Dr Jane Mathias at the Department of Psychology on the numbers provided above during working hours. If you wish to discuss the study with someone not directly involved, you may call Ms Sheila Salas, Ethics Officer, Research Services, University of South Australia, Mawson Lakes Campus, GPO Box 2471, Adelaide SA 5001, phone (08) 8302 3118, email sheila.salas@unisa.edu.au.

APPENDIX 5B

Consent form: Questionnaires and vision testing

Project Title: The Self Regulation of Driving Behaviour

Investigators:

Mr M.R.J. Baldock	PhD Student, Department of Psychology
Dr J. Mathias	Co-Investigator, Department of Psychology
Prof A.J. McLean	Co-Investigator, Road Accident Research Unit

This consent form is concerned with the questionnaires and vision testing portion of the study only.

1. The nature and purpose of the research project has been explained to me. I understand it, and agree to take part.

2. I understand that I may not directly benefit from taking part in the study.

3. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

4. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.

5. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

Name of participant: ______________________________

Signed: ______________________________

Dated: ______________________________

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed: ______________________________

(Investigator)

I would be willing to be contacted regarding future studies:

Signature of participant: ______________________________

APPENDIX 5C

Instructions given to participants for the first pilot study:

"The next task, presented on this computer in front of you, assesses both your reaction time and your ability to do more than one thing at a time. The task is comprised of two components occurring on different sides of the computer screen. Now, over here on the left side of the screen (the left side of the computer screen was pointed to by the researcher)*, there will be large black letters appearing. These letters will keep changing, and they will change at a constant rate. Your task is to react every time an "X" appears, and you must react to the appearance of an "X" by pushing the space bar* (the space bar was pointed to by the researcher) *as quickly as you can with a finger on your left hand. Every time you successfully react to an X, you will hear a sound. OK, is that all clear?"* Any clarification sought by the participant was then provided if necessary. Once the nature of the task was clear to the participant, the following was said by the researcher: *"We will begin this task by allowing you to have some practice at reacting to the Xs. You can practise for as long as you like. Just let me know when you are happy with the practice you have had and would like to move on to the next component of the task. When you are practising reacting to the Xs, you may notice that on the right side of the screen, pictures of cars appear periodically. Just ignore the cars for the moment and concentrate only on reacting to the Xs."* The task was then initiated using an inter-letter interval of 1400ms (slow) and with the secondary task, to be ignored, set so that no visual distracters (houses) were appearing. Participants were then allowed to have practice on the primary task until they indicated that they were comfortable with it. This never took longer than a few minutes.

The participants were then told: *"Now that you have had practice with the letter X task, I will get you to have some practice doing the task with the letters changing at a* *different rate. The practice you have had was at the slower rate. Now I will get you to have some practice with the letters changing a little faster. OK, is that clear?"* Again, any clarification was given, and practice was initiated, with the faster rate of letters changing (a new letter every 700ms) and the version of the secondary task, to be ignored, without the appearance of visual distracters. Participants were then allowed to have practice on the primary task until they indicated that they were comfortable with it. This never took longer than a few minutes.

Next, the participants were given the following instructions: *"Now that you are familiar with the first part of the task, I will show you the other part. Over on the right side of the screen, you may have noticed that a picture of a car appears every now and again. Your task is to respond to the appearance of the car by clicking on the left mouse button* (the left mouse button was pointed out to the participant) *with a finger on your right hand, again as quickly as you can. The cars can appear in a number of different positions, but all on the right side of the screen. Again, when you successfully detect a car, you will hear a sound. What I will get you to do now is practise doing the two tasks both at once. So what you have to do is still react to the Xs as fast as you can by pressing the space bar but, at the same time, react to the appearance of the cars by clicking the mouse button. Also, what I want you to do is concentrate the most on the letter X task. I want you to make sure that you react to every X, OK? I want you to do as well as you can on the car task but I don't want you to miss any Xs. Reacting to all the Xs is the most important part of the task. OK, is that all clear?"* Any clarification sought by the participant was then provided if necessary. Once the nature of the task was clear to the participant, the following was said by the researcher: *"Now I am going to give you some practice doing the two tasks at once. Again, you can practise for as long as you like. Just let me know when you are happy with the amount of practice you* *have had and then we will move on."* The slow version (new letter every 1400ms) of the primary task and the version of the secondary task without visual distracters were initiated. Participants all indicated that they had had enough practice after a few minutes.

Once participants had had sufficient practice on the divided attention task, the following instructions were issued by the researcher: *"Now I'd like to show you one final aspect of this task. The car detection part of the task can either be set so that it operates in the way you have practised, or it can be set so that there are distracters on the screen that make it harder to detect the cars. I am now going to show you this version of the task. In this version, as well as the cars appearing on the right side of the screen, pictures of houses appear. The houses stay on the screen the whole time but they keep moving around throughout the task. What you have to do is try and ignore the houses and only react to the cars. The houses are only there to distract you from seeing the cars. Again, you will have to perform the two tasks, the letter X task and the car task both at once, and again the most important task is the letter X task. I want you to make sure you detect every X. Try and do as well as you can reacting to the cars, but make sure you detect every X. Now I would like you to practise doing the task with the houses, and again you can have as much practice as you like. OK, is that clear?"* Again, after any clarification was given, practice was initiated. For the practice, the slow version of the primary task (a new letter every 1400ms) was utilised. Again, no participants asked for more than a few minutes of practice.

APPENDIX 5D

THE SELF-REGULATION OF DRIVING BEHAVIOUR

PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF ADELAIDE AUSTRALIA

MATTHEW BALDOCK
ROAD ACCIDENT RESEARCH UNIT
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5887

DR JANE MATHIAS
DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5266

PILOT STUDY

The Psychology Department and Road Accident Research Unit of Adelaide University are conducting a study into the "self regulation" of driving behaviour among senior drivers. The study has been designed to see if senior drivers adjust their driving habits and if so, how. The study will be useful for identifying what makes some senior drivers alter their driving habits and also whether doing so provides any safety benefits to these drivers. Before the study can commence, so-called "pilot testing" of the measures to be used in the full study is required. This involves testing a small number of volunteers and is done to ensure the practicality of the measures to be used.

If you choose to volunteer for the study, you will be asked to aid the researchers by attending the Road Accident Research Unit (Medical School South, Adelaide University) for an individual session of no more than 2 hours, in which you will be asked to complete a few tests of vision and thinking skills.

The study is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage. All information gathered in the study will be kept completely confidential. Only group statistics will be reported in any publications that result from the study. Travel to and from the University will be paid for with Cabcharge vouchers and you will be reimbursed for your time with a payment of $25.

Your written consent to participate in all aspects of the study will be sought before you start. This study has been approved by the Ethics Committee of the Department of Psychology, Adelaide University and that of the University of South Australia. If you have any concerns or wish to discuss the study you may contact Matthew Baldock at the Road Accident Research Unit or Dr Jane Mathias at the Department of Psychology on the numbers provided above during working hours. If you wish to discuss the study with someone not directly involved, you may call Ms Sheila Salas, Ethics Officer, Research Services, University of South Australia, Mawson Lakes Campus, GPO Box 2471, Adelaide SA 5001, phone (08) 8302 3118, email sheila.salas@unisa.edu.au.

APPENDIX 5E

Instructions given to participants for the second pilot study:

"The next task, presented on this computer in front of you, assesses both your reaction time and your ability to do more than one thing at a time. The task is comprised of two components occurring on different sides of the computer screen. Now, over here on the left side of the screen (the left side of the computer screen was pointed to by the researcher)*, there will be large black letters appearing. These letters will keep changing, and they will change at a constant rate. Your task is to react every time an 'X' appears, and you must react to the appearance of an 'X' by pushing the space bar* (the space bar was pointed to by the researcher) *as quickly as you can with a finger on your left hand. OK, is that all clear?"* Any clarification sought by the participant was then provided if necessary. Once the nature of the task was clear to the participant, the following was said by the researcher: *"We will begin this task by allowing you to have some practice at reacting to the Xs. You can practise for as long as you like. Just let me know when you are happy with the practice you have had and would like to move on to the next component of the task. When you are practising reacting to the Xs, you may notice that on the right side of the screen, pictures of cars appear periodically. Just ignore the cars for the moment and concentrate only on reacting to the Xs."* The task was then initiated using an inter-letter interval of 1400ms (slow) and with the secondary task to be ignored set so that no visual distracters (houses) were appearing. Participants were then allowed to have practice on the primary task until they indicated that they were comfortable with it. This never took longer than a few minutes.

The participants were then told to allow the next X to go by without reacting to it. When they did this, a sound was emitted by the computer two seconds after the appearance of the X. The participant was asked if they heard the sound. The participant was then told, *"That sound signifies that an X has appeared that was not reacted to, so if you hear that sound at any stage during the test, it means you have failed to detect an X. OK, is that clear?"* Any clarification sought by the participant was then given

The participants were then told: *"Now that you have had practice with the letter X task, I will get you to have some practice doing the task with the letters changing at a different rate. The practice you have had was at the slower rate. Now I will get you to have some practice with the letters changing a little faster. OK, is that clear?"* Again, any clarification was given, and practice was initiated, with the faster rate of letters changing (a new letter every 700ms) and the version of the secondary task, to be ignored, without the appearance of visual distracters. Participants were then allowed to have practice on the primary task until they indicated that they were comfortable with it. This never took longer than a few minutes.

Next, the participants were given the following instructions: *"Now that you are familiar with the first part of the task, I will show you the other part. Over on the right side of the screen, you may have noticed that a picture of a car appears every now and again. Your task is to respond to the appearance of the car by clicking on the left mouse button (the left mouse button was pointed out to the participant) with a finger on your right hand, again as quickly as you can. The cars can appear in a number of different positions but all on the right side of the screen. What I will get you to do now is practise doing the two tasks both at once. So what you have to do is still react to the Xs as fast as you can by pressing the space bar, but at the same time, react to the appearance of the cars by clicking the mouse button. Also, what I want you to do is keep your eyes focussed on the letters. I want you to be looking at the letters the entire* *time and making sure you get all of the Xs. Thus, I want you to be detecting the cars using your peripheral vision only, so you are only seeing them out of the corner of your eye while focussing directly on the letters. OK, is that all clear?"* Any clarification sought by the participant was then provided if necessary. Once the nature of the task was clear to the participant, the following was said by the researcher: *"Now I am going to give you some practice doing the two tasks at once. Again, you can practise for as long as you like. Just let me know when you are happy with the amount of practice you have had and then we will move on."* The slow version (new letter every 1400ms) of the primary task and the version of the secondary task without the visual distracters were initiated. Participants all indicated that they had had enough practice after a few minutes.

Once participants had completed sufficient practice trials on the divided attention task, the following instructions were issued by the researcher: *"Now I'd like to show you one final aspect of this task. The car detection part of the task can either be set so that it operates in the way you have practised, or it can be set so that there are distracters on the screen that make it harder to detect the cars. I am now going to show you this version of the task. In this version, as well as the cars appearing on the right side of the screen, pictures of houses appear as well. The houses stay on the screen the whole time but they keep moving around throughout the task. What you have to do is try and ignore the houses and only react to the cars. The houses are only there to distract you from seeing the cars. Again, you will have to perform the two tasks, the letter X task and the car task both at once, and again I want you to focus your eyes on the letters, making sure you detect all the Xs, and only seeing the cars using your side vision. I do not want you looking directly at the right side of the screen to see the cars. I want you looking directly at the letters and trying to detect cars out of the corner of your eye.*

Now I would like you to practise doing the task with the houses, and again you can have as much practice as you like. OK, is that clear?" Again, after any clarification was given, practice was initiated. For the practice, the slow version of the primary task (a new letter every 1400ms) was utilised. Again, no participants asked for more than a few minutes of practice.

APPENDIX 5F

Ordering of the attention tasks in the second pilot study:

The eight different tasks were given numbers from one to eight according to the following number scheme:

1: primary task only, slow rate of presentation

2: primary task only, fast rate of presentation

3: secondary task only, no visual distracters

4: secondary task only, visual distracters

5: dual task, slow rate of presentation, no visual distracters

6: dual task, fast rate of presentation, no visual distracters

7: dual task, slow rate of presentation, visual distracters

8: dual task, fast rate of presentation, visual distracters

Using this numbering system, the following eight orders of the above tasks were used:

12 34 56 78

56 78 12 34

34 12 78 56

78 56 34 12

21 43 65 87

65 87 21 43

43 21 87 65

87 65 43 21

APPENDIX 6A

QUESTIONS USED IN THE 'DRIVER MOBILITY QUESTIONNAIRE'

Background
1) What is your age in years? ______ (number of years)
2) Are you male or female? ☐male ☐female
3) Have you held a valid driver's licence for more than ten years? ☐yes ☐no

Medical conditions
1) Do you suffer from glaucoma? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
2) Do you suffer from cataract? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
3) Do you suffer from macular degeneration? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
4) Do you suffer from diabetic retinopathy (visual problem caused by diabetes)?
    ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
5) Have you had a stroke or transient ischaemic attack? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
6) Do you suffer from heart disease? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
7) Do you suffer from arrhythmia (irregular heartbeat)? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
8) Do you suffer from cancer? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
9) Do you suffer from arthritis? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
10) Do you suffer from Alzheimer's Disease? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
11) Do you suffer from Parkinson's Disease? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
12) Do you suffer from epilepsy? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
13) Do you suffer from diabetes? ☐ yes ☐ no
    if yes, how much does it affect your daily functioning?
    ☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all

14) Do you suffer from sleep apnoea? ☐ yes ☐ no
if yes, how much does it affect your daily functioning?
☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all

15) Do you suffer from any other medical conditions not listed? ☐ yes ☐ no
if yes, what other condition(s) do you suffer from?
____
how much does it affect your daily functioning?
☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
how much does it affect your daily functioning?
☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all
how much does it affect your daily functioning?
☐ it affects it a lot ☐ it affects it a bit ☐ it does not affect it at all

16) What medications do you take regularly (more than once a month)?
____________________ ________________________
____________________ ________________________

Driving Habits

Current Driving

1) Which way do you prefer to get around
- ☐ drive yourself
- ☐ have someone drive you
- ☐ public transportation or taxi

2) Do you wear glasses or contact lenses when you drive? ☐ yes ☐ no

3) When driving yourself, how fast do you usually drive compared to the general flow of traffic?
- ☐ much faster
- ☐ somewhat faster
- ☐ about the same
- ☐ somewhat slower
- ☐ much slower

4) Has anyone suggested to you over the past year that you limit your driving or stop driving? ☐ yes ☐ no
if yes, who suggested that you limit your driving or stop driving?
☐ spouse ☐ child ☐ other relative ☐ friend ☐ medical practitioner ☐ other

5) How would you rate the quality of your driving compared to the average driver?
- ☐ excellent
- ☐ good
- ☐ average
- ☐ fair
- ☐ poor

6) How would you rate your vision compared to the average driver?
- ☐ excellent
- ☐ good
- ☐ average
- ☐ fair
- ☐ poor

7) How would you rate your ability to perform more than one task at once compared to the average driver?

☐ excellent
☐ good
☐ average
☐ fair
☐ poor

8) How much do you agree with this statement?: "I would be the best person to determine when I should give up driving?"

☐ strongly agree
☐ agree
☐ disagree
☐ strongly disagree

Driving exposure

9) In an average week, how many days per week do you normally drive?

_________________ (number of days)

10) How many trips would you make in a typical week?

_________________ (number of trips)

11) Approximately how many kilometres would you drive in a typical week?

_________________ (number of kilometres)

12) Have you reduced the amount of driving you do compared to ten years ago?

☐ yes ☐ no

if yes, what are the reasons for this reduction in driving?

☐ a) save money
☐ b) don't need to drive as much now
☐ c) problems with vision
☐ d) physical problems
☐ e) problems dealing with other traffic
☐ f) other (please specify)

Which of these is the main reason? _______ (letter a, b, c, d, e or f)

Confidence

Answer the following questions by placing the appropriate number in the space provided in the right hand margin.

1 - - - - - - - - - -	2 - - - - - - - - - -	3 - - - - - - - - - -	4 - - - - - - - - - -	5
not confident at all	not very confident	reasonably confident	very confident	completely confident

13) How confident are you driving when it is raining? ______
14) How confident are you driving when alone? ______
15) How confident are you when having to reverse parallel park? ______
16) How confident are you when having to turn right across traffic? ______
17) How confident are you driving on a freeway or high speed highway? ______
18) How confident are you driving on high traffic roads? ______
19) How confident are you driving in peak hour traffic? ______
20) How confident are you driving at night? ______
21) How confident are you driving at night in the rain? ______

Crashes and citations

22) How many accidents have you been involved in over the past five years when you were the driver? ________ (number of accidents)

23) How many accidents have you been involved in over the past five years when you were the driver and the police were called to the scene? _________ (number of accidents)

24) How many times in the last five years have you been pulled over by the police when driving, regardless of whether you received a ticket (excluding random breath testing)? _________ (number of times pulled over)

25) How many times in the last five years have you received a traffic ticket (other than a parking ticket) where you were found to be guilty? _________ (number of times received a ticket)

Driving space

26) During the past year, have you driven in your immediate neighbourhood?
☐ yes ☐ no

27) During the past year, have you driven to places beyond your neighbourhood?
☐ yes ☐ no

28) During the past year, have you driven to a part of the city you are not familiar with?
☐ yes ☐ no

29) During the past year, have you driven outside the metropolitan area?
☐ yes ☐ no

30) During the past year, have you driven outside the state of South Australia?
☐ yes ☐ no

Driving avoidance

Answer the following questions by placing the appropriate number in the space provided in the right hand margin.

1 - - - - - - - - - - 2 - - - - - - - - - - 3 - - - - - - - - - - 4 - - - - - - - - - - 5
never rarely sometimes often always

31) During the past year, have you avoided driving when it is raining? _____
32) During the past year, have you avoided driving when alone? _____
33) During the past year, have you avoided reverse parallel parking? _____
34) During the past year, have you avoided making right turns across traffic? _____
35) During the past year, have you avoided driving on a freeway or high speed highway? _____
36) During the past year, have you avoided driving on high traffic roads? _____
37) During the past year, have you avoided driving in peak hour traffic? _____
38) During the past year, have you avoided driving at night? _____
39) During the past year, have you avoided driving at night in the rain? _____

Perceived barriers

Answer the following questions by placing the appropriate number in the space provided in the right hand margin.

1 - - - - - - - - - - -	2 - - - - - - - - - -	3 - - - - - - - - - -	4
strongly disagree	disagree	agree	strongly agree

40) Changing when and where you drive would not be possible given your lifestyle and the places you need to go _____

41) Changing when and where you drive would not be possible because other people count on you to drive them _____

42) Changing when and where you drive would not be possible because public transport is not available to you _____

43) Changing when and where you drive would not be possible because you don't want to use public transportation _____

44) Changing when and where you drive would not be possible because your friends/family are unavailable _____

45) Changing when and where you drive would not be possible because you don't want to ask family/friends to drive _____

Regulatory self-efficacy

Answer the following questions by placing the appropriate number in the space provided in the right hand margin.

1 - - - - - - - - - -	2 - - - - - - - - - -	3
very hard	somewhat hard	not hard at all

46) How hard would it be for you to organise your life so that you do most of your driving when it is not raining? _____

47) How hard would it be for you to organise your life so that you drive with someone else in the car with you instead of driving alone? _____

48) How hard would it be for you to organise your life so that you park mostly in designated parking spaces instead of reverse parallel parking? _____

49) How hard would it be for you to organise your life so that you make left turns rather than right turns across traffic? _____

50) How hard would it be for you to organise your life so that you do most of your driving on city streets instead of driving on freeways or high speed highways? _____

51) How hard would it be for you to organise your life so that you do your driving on roads with little traffic instead of high traffic roads? _____

52) How hard would it be for you to organise your life so that you do most of your driving at times other than peak hour? _____

53) How hard would it be for you to organise your life so that you drive during daylight hours instead of driving at night? _____

APPENDIX 6B

The Driver Mobility Questionnaire used in the present study included a number of questions taken from the Driving Habits Questionnaire (DHQ) from Owsley et al. (1999) and the Driver Perceptions and Practices Questionnaire from Stalvey and Owsley (2000). Some alterations to some of the questions were necessary, however, in order to obtain the desired information and also to tailor the questions to suit drivers in South Australia rather than the USA. The details of these alterations are provided below.

The “Current driving” section of the Driver Mobility Questionnaire includes questions 4, 6, 7, 8 and 9 from the DHQ. For question 8 (“Has anyone suggested over the past year that you limit your driving or stop driving?”), participants who answered “yes” were asked to nominate who had made the suggestion and were given the options of spouse, child, other relative, friend, medical practitioner or other. For question 9 (“How would you rate the quality of your driving?”), the words “compared to the average driver” were added. Participants were also asked to rate their vision and ability to perform more than one task at once compared to the average driver.

The “Driving exposure” section was based on the Exposure questions from the DHQ but these were altered so that participants simply had to provide estimates of the number of days driven per week, the number of trips taken per week and the number of kilometres driven per week. This was done to simplify the DHQ questions in which participants must list all of their trips and separately calculate the mileage associated with each. An additional question asked whether participants had reduced the amount of driving they do in the past ten years. If participants answered “yes”, they were asked to nominate the main reason for this, with options provided being: to save money, don’t need to drive as much now, problems with vision, physical problems, problems dealing with other traffic, other (please specify).

Questions concerning “Confidence” and “Avoidance” in the Driver Mobility Questionnaire were based on the “Difficulty” section of the DHQ and supplementary questions used by Stalvey and Owsley (2000). Differences include that the time period asked about in the avoidance questions was increased from the past three months to the past year (in order to make it commensurate with the time period for which crashes were asked about - see below), and the addition of questions regarding confidence in, and avoidance of, driving at night in the rain. It was thought that the combination of night time darkness and reduced visibility caused by rain and wet roads might pose particular difficulty to older drivers.

The “Crashes and citations” section of the Driver Mobility Questionnaire was based on questions 25 to 28 of the DHQ. The only change was the addition of the words “excluding random breath testing” to the question about being pulled over by the police. Drivers in Australia may be pulled over for random breath testing despite giving no indication of any driving problems and such situations were irrelevant to questions concerned with identifying indications of driving difficulties.

The “Driving space” section of the questionnaire was taken from questions 29 to 34 in the DHQ but a number of adjustments had to be made to make the questions suitable for respondents living in Adelaide, South Australia. Instead of questions about driving to neighbouring towns or more distant towns, the Driver Mobility Questionnaire just had a single question about parts of the city with which participants were not familiar. Questions 33 and 34 in the DHQ asked about driving outside the state and outside the southeast of the USA, respectively, but, given the greater size of South Australia compared to states in the USA, participants in the present study were asked instead if they had driven outside of the metropolitan area (of Adelaide) and if they had driven outside of the state (of South Australia).

Items in the Driver Mobility Questionnaire concerned with "Perceived barriers to self-regulation" were based on items 35 to 41 from the Driver Perceptions and Practices Questionnaire, with one item (36: "Changing when/where I drive is not possible because of how I have to get from one place to another") omitted.

Finally, the "Regulatory self-efficacy" section of the questionnaire was based on questions 55 to 61 from the Driver Perceptions and Practices Questionnaire. The questions were altered slightly so that instead of saying, for example, "How hard would it be for you to do most of your driving when it is not raining?", they said, for example, "How hard would it be for you to organise your life so that you did most of your driving when it is not raining?" This was done so that the questions emphasised that participants were being asked about adjustments to their driving habits that, in many cases, would require adjustments to their lifestyles.

APPENDIX 6C

DARS / UNISA ON-ROAD ASSESSMENT

(Developed by Angela Berndt 2002:
Contributions by Pamela Dean and Mareeta Dolling 2001
Task Matched to On-Road Assessment developed by R. Lister 1998)

Client Name:	**Vehicle:**
ID Number:	**Time:**
OT:	**DI:**
Date:	**Weather:**

FAMILIARISATION PERIOD
Begin @ Twelftree Reserve Torrens St. Hackney

INSTRUCTIONS AND LOCATIONS	OBSERVATIONS	SCORE	COMMENTS
1. *Starting in the parked kerb side potion:* Make yourself comfortable in the seat and when ready, start the car.	a) Adjust seat position b) Adjust mirrors c) Fasten seatbelt d) Put key in engine e) Start engine	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO	
2. Drive Straight ahead, follow the road.	a) Apply foot brake b) Select drive c) Observation / BS d) Mirror e) Indicate to move off f) Speed g) Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
3. At the School Zone			
4. *At 5th St:* On the second road on your left, TURN LEFT. (*into Third Ave.)*			**Comments on ability to follow instructions, type of error, type of feedback provided by DI to reinforce process.**
5. At the Roundabout, TURN LEFT. (*into St. Peters St.)*			
6. Follow the Road.			
7. *When @ 5thSt. RAB,* At the second road on the left, TURN LEFT *(into Harrow Rd.)*			
8. Repeat left and right turns for 10 minutes.	**Return to start.**		
9. Please park alongside the kerb and secure the vehicle. (Engine to remain running)	a) Speed of approach b) Positioning c) Observation d) Indicator e) Select Park f) Hand brake	1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO	**SCORE FAM. PHASE /18**
BEGIN NOW:			
INSTRUCTIONS AND LOCATIONS	**OBSERVATIONS**	**SCORE**	**COMMENTS**

1. Drive Straight ahead, follow the road.	a) Apply foot brake b) Select drive c) Observation / BS d) Mirror e) Indicate to move off f) Speed g) Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
2. At the School Zone	a) Speed	1 =Correct 0 =Incorrect	
3. *At 5th St:* On the second road on your left, TURN LEFT. (*into Third Ave.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
4. At the Roundabout, TURN LEFT. (*into St. Peters St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
5. At the 4th St. RAB, continue ahead.	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
6. At the next turn to left, TURN LEFT (*into 5th St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
7. At the end of the road, TURN LEFT. *(into Harrow Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation @ GW e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
8. At the second road on your right, TURN RIGHT. *(into Rugby St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
9. At the RAB, TURN RIGHT. *(into Marlborough St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
10. At the end of the road, TURN RIGHT. (*into College St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	

11. At the end of the road, TURN LEFT. *(into Harrow Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation @ GW e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
12. *When at Magdalen St,* At the second road on the left, TURN LEFT. *(into Richmond St.)* *At* School Zone	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Speed	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
13. At DIP on Richmond St.	a) Speed of approach	1 = Safe 0 = Unsafe	
14. At next road on left, TURN LEFT. (*into Eton Lane).*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
15. Whilst in Eton Lane, Speed Humps	a) Speed of approach	1 = Safe 0 = Unsafe	
16. End of lane, Stop Sign.	a) Mirror b) Speed of approach c) Stop	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO	
17. Continue ahead, Into Pembroke St.	a) Mirror b) Indicator c) Observation d) Gap selection e) Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
18. At the School Zone	a) Speed	1 =Correct 0 =Incorrect	
19. At the end of road, TURN LEFT, *(into Rugby St.)* @ Stop Sign.	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning c) Stop	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO	
20. At the end of the road we will cross over and continue ahead. *(into 2nd Ave.)* @ Stop Sign.	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning c) Stop	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO	
21. At the RAB, TURN LEFT (*into St Peters St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	

22. At the 3rd Av. RAB, continue ahead.	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
23. At the 4th Av. RAB, continue ahead. *(prepare to turn right into 5th Av.)*	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
24. At the next TURN to the right, TURN RIGHT. *(into 5th Av.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
25. At the next intersection, TURN RIGHT. *(into Stephens Tce.)*	a) Mirror b) Speed of approach c) Indicator d) Observation @GW e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
26. At the second turn to the left, TURN LEFT. *(into 3rd Ave.)* @ School zone	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Speed	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
27. At the second road to the right, TURN RIGHT. *(into Winchester St.)* @ School zone	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Speed	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
28. At the 2nd Ave. RAB, continue ahead.	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
29. At the 1st. Ave RAB, continue ahead.	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
END LOW DEMAND EXIT POINT TO FIRST AVE. IF REQUIRED.		**SCORE LOW DEMAND =**	**/151**

BEGIN MODERATE DEMAND	OBSERVATIONS	SCORE	COMMENTS
30. At the end of the road, TURN LEFT *(into Payneham Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
31. Follow the Road	a) Mirror b) Observation c) Speed d)Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
32. At traffic lights	a) Response to lights	1 =Correct 0 =Incorrect	
33. At the next set of traffic lights ahead, TURN LEFT. *(into Portrush Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
34. *Once past shopping Centre:* When it is safe to do so, please move one lane to the RIGHT	a) Mirror b) Speed c) Indicator d) Observation / BS e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
35. When you see a safe place to do a U-turn, please do a U-turn	a) Selects location a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
36. Follow the Road	a) Mirror b) Observation c) Speed d)Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
37. At the next set of traffic lights ahead, Continue ahead. *(into Portrush Rd.)*	a) Mirror b) Speed of approach c) Observation d) Gap selection e) Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
38. Follow the road. @ Pedestrian Crossing	a) Mirror b) Observation c) Speed d) Positioning a) Response to lights	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
39. When it is safe to do so, please move one lane to the RIGHT	a) Mirror b) Speed c) Indicator d) Observation / BS e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	

40. Follow the road. @ Pedestrian Crossing	a) Mirror b) Observation c) Speed d) Positioning a) Response to lights	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
41. *(when @ Devitt Ave School)* At the second road to the right, TURN RIGHT. *(into Clifton St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
42. Speed Humps	a) Speed of approach	1 = Safe 0 = Unsafe	
43. At the Phillips St. RAB, continue ahead.	a) Mirror b) Speed of approach d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
44. At the 2nd road on the left, TURN LEFT. *(into Frederick St..)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
45. *When around the corner,* Please find a safe place at the side of the road to park the car.	a) Selects location b) Mirror c) Indicator d) Positioning	1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe	
46. When you are ready, move off and continue down the road	a) Indicator b) Mirror c) Blind spot d) Gap selection	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe	
47. At the end of the road, TURN LEFT. *(into Magill Rd.)* @ Stop Sign	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Stop	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO	
48. When it is safe to do so, please move one lane to the RIGHT	a) Mirror b) Speed c) Indicator d) Observation / BS e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
49. At the traffic lights, TURN RIGHT. *(into Portrush Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	

50. Follow the road.	a) Mirror b) Observation c) Speed d) Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
51. At the traffic lights, TURN RIGHT. *(into Portrush Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
END MODERATE DEMAND	**EXIT POINT TO BEULAH RD. IF REQUIRED.**	**SCORE MODERATE DEMAND =**	**/113**
BEGIN HIGH DEMAND	**OBSERVATIONS**	**SCORE**	**COMMENTS**
52. At the traffic lights, TURN RIGHT. *(into Norwood Pde.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
53. At the traffic lights, TURN RIGHT. *(into George St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
54. At the next turn, TURN LEFT NO ENTRY @ ONE WAY SIGN *(into Harris St.)*	a) Response to signs a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
55. Go into the carpark and when you can see a safe place to park, park the car please. *Once parked:* Please reverse out of here and exit the way	a) Selects parking bay b) Direction in carpark a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning g) Park gear h) Handbrake a) Mirror b) Reverse gear c) Indicator	1 =Correct 0 =Incorrect 1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO	

we came in.	d) Observation e) Gap selection f) Positioning h) Handbrake i) Direction in carpark	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 =Correct 0 =Incorrect	
56. LEFT TURN, *(into Harris St.)*	a) Response to sign	1 =Correct 0 =Incorrect	
57. At the end of the road, TURN RIGHT *(into Edward St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
58. At the RAB, TURN LEFT *(into Beulah Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
59. Follow the road. ONE WAY Sign *(into Osmond Tce.)*	a) Response to sign a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f) Positioning	1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
60. Follow the road. @ Pedestrian Crossing	a) Mirror b) Observation c) Speed d) Positioning a) Response to lights	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
61. At the traffic lights, TURN RIGHT. *(into Norwood Pde.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
62. Follow the road. Continue @ Traffic Lights *(Fullarton Rd into Parade West)*	a) Mirror b) Observation c) Speed d) Positioning a) Response to lights	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	

63. Follow the road. *Merging with traffic on the other side of intersection.* *Whilst driving around curve in road.* School Zone Pedestrian Island	a) Mirror b) Observation BS c) Indicator b) Speed e) Gap selection c) Positioning c) Positioning (bikelane) a) Speed b) Observation	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0=Incorrect 1 = YES 0 = NO	
64. At the end of the road, TURN LEFT *(into Rundle St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation @ GW e) Gap selection f) Positioning	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
65. At the traffic lights, TURN RIGHT, *(into Deq. Tce.)* Lane Changes Followed by a LEFT TURN at the next set of lights. *(into Botanic Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights a) Choice of lane a) Mirror b) Indicator c) BS observation d) Gap selection e) Positioning a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect 1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
66. Bus Lane	a) Positioning	1 = Safe 0 = Unsafe	
67. At the traffic lights, TURN LEFT, *(into East. Tce.)* Lane Changes	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights a) Choice of lane	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect 1 =Correct 0 =Incorrect	

	a) Mirror b) Indicator c) BS observation d) Gap selection e) Positioning	1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe	
Followed by a RIGHT TURN at the next set of lights. *(into Rundle St.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
68. At the next traffic lights, TURN RIGHT *(into Frome Rd.)*	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
69. Follow the road. Continue @ Traffic Lights *(across Nth. Tce.)*	a) Mirror b) Observation c) Speed d) Positioning a) Response to lights	1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
70. After the pedestrian crossing, please TURN LEFT into Gate 5.	a) Mirror b) Speed of approach c) Indicator d) Observation e) Gap selection f)Positioning a) Response to lights	1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = Safe 0 = Unsafe 1 =Correct 0 =Incorrect	
71. Please park in the last bay on the left	a) Selects parking bay b) Indicator c) Positioning d) Selects park gear e) Applies handbrake f) Turns engine off	1 =Correct 0 =Incorrect 1 = YES 0 = NO 1 = Safe 0 = Unsafe 1 = YES 0 = NO 1 = YES 0 = NO 1 = YES 0 = NO	
END HIGH DEMAND		**SCORE HIGH DEMAND**	**/ 157**
SCORE LOW (151)	**SCORE MODERATE (113)**	**SCORE HIGH (157)**	**TOTAL ASSESSMENT SCORE: /421**

GENERAL COMMENTS:
<u>FEEDBACK FROM DI:</u>

APPENDIX 6D

SCORING KEY

A. POINTS SCORED ON A YES/NO BASIS

Indicator, Adjust seat, Adjust mirror, Key in, Start engine, Apply brake, Select Drive, Select Park, Select Reverse, Engine off, Apply hand brake

Score Yes
- if the action is observed and completed by the participant independently.

Score No
- if the action is not observed.
- if the participant required assistance to complete the action.

Observation

Score Yes
- if participant turns their head or shifts gaze to look for vehicles etc.

Score No
- if they do not turn their head or shift their gaze.

Stop

Score Yes
- if participant brings the car to a complete stop

Score No
- if participant does not bring the car to a complete stop.

Mirror Check

Score Yes
- if participant looks in the central and/ or side mirrors

Score No
- if participant does not look in these mirrors.

B. POINTS SCORED ON A SAFE/UNSAFE BASIS

Speed

Score Safe
- if participant drives under the speed limit
- if participant drives at an appropriate speed for the traffic environment

Score Unsafe
- if participant drives over the speed limit
- if participant drives at an inappropriate speed for the environment

Positioning

Score Safe
- if participant parks at the side of the road with 2 tyres in the gutter
- if participant allows a safe distance between the test vehicle and other vehicles when parking
- if participant parks wholly within a parking bay
- if participant keeps as close as practical to left side of the road on unlaned roads.
- if participant stays wholly within their lane on laned roads (grant an exception if moves out around parked cars as long as they then move back completely into the lane again once past the cars or do a lane change).
- if participant allows a safe distance between the test vehicle and parked cars on the side of the road.

Score Unsafe
- if participant drives in a bike lane
- if participant straddles lanes on laned roads (includes not changing lanes on roads where parked cars take up part of the outside lane).
- if participant drives in the centre of an unlaned road rather than keeping to the left.
- if participant mounts the kerb when undertaking a turn
- if participant cuts a corner when turning (i.e. does not keep left of the centre of the road when turning)
- if participant drifts toward an adjacent lane or the side of the road.

Speed of approach

Score Safe
- if participant drives at a speed that allows them to control the vehicle safely when negotiating a corner, dip or speed hump without unnecessarily holding up other traffic.

Score Unsafe
- if participant drives at a speed that is too fast to permit them to position the car safely on turns or results in driving over dips/speed humps harshly.
- if participant is required to brake harshly at a corner, dip or speed hump
- if participant approaches a corner, dip or speed hump at a speed that is unnecessarily slow.

Gap Selection

Score safe
- if participant enters a road without causing other vehicles to brake

Score Unsafe
- if participant enters traffic where there was insufficient room to do so causing other vehicles to brake.
- if participant gives way unnecessarily at an intersection.

C. POINTS SCORED ON A PASS / FAIL BASIS

Following instructions

Score Pass
- if participants complete requested actions after the instructor has given them up to 2 times.

Score Fail
- if participant does not complete requested actions after they have been given it up to 2 times.

Familiarisation Period

Score Pass
- if participants are able to negotiate at least 3 of the left turns without physical assistance from the driving instructor.
- if participants are able to follow instructions.

Score Fail
- if participants are unable to follow instructions
- if participants require physical intervention by the instructor on more than one turn.
- if participants have any accidents.

D. POINTS SCORED ON A CORRECT/INCORRECT BASIS

Response to lights

Score Correct
- if participant responds as the law states.

Score Incorrect
- if participant drives against a red light
- if participant drives through an orange light when they were able to stop safely.
- if participant fails to move off on a green light
- if participant fails to give way to oncoming traffic when turning right at lights where there is no turning arrow.

Speed at school zone

Score Correct
- if participant drives at 25 km/hr when children are present

Score Incorrect
- if participant drives in excess of 25 km/hr when children are present
- if participant drives at 25 km/hr when no children are present.

Choice of lane

Score Correct
- if participant positions self in a lane that will enable them to safely negotiate the next turn without needing to change lanes.

Score Incorrect
- if participant positions self in a lane that will require them to perform a lane change quickly in order to be in a position to turn at the next comer.

Selects location to park

Score Correct
- if participant chooses to park in a location where parking is permitted at that time.

Score Incorrect
- if participant chooses to park in a place signposted "no parking"
- if participant parks across a driveway
- if participant parks in a disabled parking bay
- if participant parks across a walkway.

Selects location to do a U-turn

Score Correct
- if participant chooses to negotiate a U-turn in a place where U-turns are permitted

Score Incorrect
- if participant chooses to negotiate a U-turn in a place where there is a "no U-turn" sign or at traffic lights.

APPENDIX 6E

THE SELF-REGULATION OF DRIVING BEHAVIOUR

PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF ADELAIDE AUSTRALIA

MATTHEW BALDOCK
ROAD ACCIDENT RESEARCH UNIT
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5887

DR JANE MATHIAS
DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5266

The Psychology Department and Road Accident Research Unit of the University of Adelaide are conducting a study into the "self regulation" of driving behaviour among senior drivers. The study has been designed to see if senior drivers adjust their driving habits and if so, how. The study will be useful for identifying what makes some senior drivers alter their driving habits and also whether doing so provides any safety benefits to these drivers.

If you choose to volunteer for the study, you will be asked to aid the researchers in the following ways:

1) By completing in your own time a small number of questionnaires about driving habits and medical conditions you might have. These will be posted to you and should take no more than 30 minutes.

2) By attending the Road Accident Research Unit (Medical School South, University of Adelaide) for an individual session of around 1.5 to 2 hours, in which you will be asked to complete a few tests of vision and thinking skills.

3) Additionally, you will be asked to provide your drivers licence number so that your driving licence details can be checked on an official database. Note: if you do not wish to provide this information, you do not have to. You can participate in the rest of the study without providing your licence number.

4) By agreeing to a free on-road driving assessment. This service, which normally costs $165, will be provided free. It involves coming in to the University of South Australia and performing an on-road test with qualified professional personnel who will be able to give you feedback on your driving. If this driving test reveals significant problems, a letter will be sent to your GP who will decide what, if any, action is required. This session will take about 1.5 hours, of which one hour is spent on the road. Note: again, you may participate in the other aspects of the study without having to volunteer for the on-road test.

The study is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage. All information gathered in the study will be kept completely confidential. Only group statistics will be reported in any publications that result from the study. Travel to and from the University will be paid for with Cabcharge vouchers and you will be reimbursed for your time with a payment of $25 for the questionnaires and tests of vision and thinking skills and $25 for the on-road driving test.

Your written consent to participate in all aspects of the study will be sought before you start. Consent for the different aspects of the study will be sought using separate consent forms. **You do not have to give consent to participate in all parts of the study if you do not want to.**

This study has been approved by the Ethics Committee of the Department of Psychology, University of Adelaide. If you have any concerns or wish to discuss the study you may contact Matthew Baldock at the Road Accident Research Unit or Dr Jane Mathias on the numbers provided above during working hours. If you wish to discuss the study with someone not directly involved, you may call Dr Peter Delin, Convenor of the Departmental Ethics Committee, on 8303 5007.

APPENDIX 6F

SELF-REGULATION OF DRIVING BEHAVIOUR

PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF ADELAIDE AUSTRALIA

MATTHEW BALDOCK
ROAD ACCIDENT RESEARCH UNIT
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5887

DR JANE MATHIAS
DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5266

The Psychology Department and Road Accident Research Unit of the University of Adelaide are conducting a study into the "self regulation" of driving behaviour among senior drivers. The study has been designed to see if senior drivers adjust their driving habits and if so, how. The study will be useful for identifying what makes some senior drivers alter their driving habits and also whether doing so provides any safety benefits to these drivers.

If you choose to volunteer for the study, you will be asked to aid the researchers in the following ways:

1) By completing in your own time a small number of questionnaires about driving habits prior to your assessment and medical conditions you might have. These will be posted to you and should take no more than 30 minutes.

2) By attending the Road Accident Research Unit (Medical School South, University of Adelaide) for an individual session of around 1.5 to 2 hours, in which you will be asked to complete a few tests of vision and thinking skills.

3) Additionally, you will be asked to provide your drivers licence number so that your driving licence details can be checked on an official database. Note: if you do not wish to provide this information, you do not have to. You can participate in the rest of the study without providing your licence number.

4) By giving permission to the investigators to gain access to the results of your driving assessment with the Driver Assessment Rehabilitation Service. Note: again, if you do not wish to provide this information, you do not have to. You can participate in the rest of the study without providing access to the results of your driving assessment.

The study is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage. All information gathered in the study will be kept completely confidential. Only group statistics will be reported in any publications that result from the study. Travel to and from the University will be paid for with Cabcharge vouchers and you will be reimbursed for your time with a payment of $25.

Your written consent to participate in all aspects of the study will be sought before you start. Consent for the different aspects of the study will be sought using separate consent forms.

This study has been approved by the Ethics Committee of the Department of Psychology, the University of Adelaide and that of the University of South Australia. If you have any concerns or wish to discuss the study you may contact Matthew Baldock at the Road Accident Research Unit or Dr Jane Mathias at the Department of Psychology on the numbers provided above during working hours. If you wish to discuss the study with someone not directly involved, you may call Ms Sheila Salas, Ethics Officer, Research Services, University of South Australia, Mawson Lakes Campus, GPO Box 2471, Adelaide SA 5001, phone (08) 8302 3118, email sheila.salas@unisa.edu.au.

APPENDIX 6G

Consent form: Licence numbers

Project Title: The Self Regulation of Driving Behaviour

Investigators:

Mr M.R.J. Baldock	PhD Student, Department of Psychology
Dr J. Mathias	Co-Investigator, Department of Psychology
Prof A.J. McLean	Co-Investigator, Road Accident Research Unit

This consent from is concerned with the use of licence numbers to view driving records only.

6. The nature and purpose of this aspect of the research project has been explained to me. I understand it, and agree to take part.

7. I understand that I may not directly benefit from taking part in the study.

8. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

9. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.

10. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

Name of participant: ________________________________

Signed: ________________________________

Dated: ________________________________

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed: ________________________________

(Investigator)

APPENDIX 6H

Consent form: On-road assessment

Project Title: The Self Regulation of Driving Behaviour

Investigators:

Mr M.R.J. Baldock	PhD Student, Department of Psychology
Dr J. Mathias	Co-Investigator, Department of Psychology
Prof A.J. McLean	Co-Investigator, Road Accident Research Unit

This consent form is concerned with the on-road driving assessment aspect of the study only.

11. The nature and purpose of this aspect of the research project has been explained to me. I understand it, and agree to take part.

12. I understand that I may not directly benefit from taking part in the study.

13. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

14. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.

15. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

Name of participant: ______________________________

Signed: ______________________________

Dated: ______________________________

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed: ______________________________

(Investigator)

APPENDIX 6I

Consent form: On-road assessment

Project Title: The Self Regulation of Driving Behaviour

Investigators:

Mr M.R.J. Baldock	PhD Student, Department of Psychology
Dr J. Mathias	Co-Investigator, Department of Psychology
Prof A.J. McLean	Co-Investigator, Road Accident Research Unit

This consent form is concerned only with the permission for access to the results of the on-road driving assessment at the Driver Assessment Rehabilitation Service.

16. The nature and purpose of this aspect of the research project has been explained to me. I understand it, and agree to take part.

17. I understand that I may not directly benefit from taking part in the study.

18. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

19. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

Name of participant: ______________________________

Signed: ______________________________

Dated: ______________________________

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed: ______________________________

(Investigator)

APPENDIX 6J

VISUAL ATTENTION TEST VALIDATION STUDY

PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF ADELAIDE AUSTRALIA

MATTHEW BALDOCK
ROAD ACCIDENT RESEARCH UNIT
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5887

DR JANE MATHIAS
DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF ADELAIDE
TELEPHONE: +61 8 8303 5266

The Psychology Department and Road Accident Research Unit of the University of Adelaide are conducting a study aiming to validate a test of "visual attention" used in another study into the "self regulation" of driving behaviour among drivers aged over 55. The study has been designed to see if the visual attention test measures similar abilities to other well-established tests of attention, and if it produces reliable results over repeated performances of the test.

If you choose to volunteer for the study, you will be asked to aid the researchers by attending the Road Accident Research Unit (Medical School South, University of Adelaide) for an individual session of less than 1.5 hours, in which you will be asked to complete a few tests of visual and thinking skills.

The study is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage. All information gathered in the study will be kept completely confidential. Only group statistics will be reported in any publications that result from the study. Travel to and from the University will be paid for with Cabcharge vouchers and you will be reimbursed for your time with a payment of $25.

Your written consent to participate in the study will be sought before you start.

This study has been approved by the Ethics Committee of the Department of Psychology, University of Adelaide. If you have any concerns or wish to discuss the study you may contact Matthew Baldock at the Road Accident Research Unit or Dr Jane Mathias on the numbers provided above during working hours. If you wish to discuss the study with someone not directly involved, you may call Dr Paul Delfabbro, Convenor of the Departmental Ethics Committee, on 8303 5744.

APPENDIX 6K

Consent form: Visual attention testing

Project Title: The Validation of the Visual Attention Test

Investigators:

Mr M.R.J. Baldock	PhD Student, Department of Psychology
Dr J. Mathias	Co-Investigator, Department of Psychology
Prof A.J. McLean	Co-Investigator, Road Accident Research Unit

20. The nature and purpose of the research project has been explained to me. I understand it, and agree to take part.

21. I understand that I may not directly benefit from taking part in the study.

22. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

23. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.

24. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

Name of participant: ______________________________

Signed: ______________________________

Dated: ______________________________

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed: ______________________________

(Investigator)

APPENDIX 8

Inter-correlations between candidate predictor variables for a regression procedure predicting driving performance (n = 90)

Variable	1	2	3	4	5	6	7
1 Age	1.00	-.25	-.42	-.41	-.18	.21	.01
2 CS left		1.00	.55	.16	.11	-.34	-.27
3 CS binocular			1.00	-.28	.07	-.22	-.11
4 Symbol Digit				1.00	.51	-.34	-.04
5 Spatial Span total					1.00	-.16	-.02
6 XRT, single						1.00	.65
7 car RT, sing, no distract							1.00
8 car RT, sing, distract							
9 XRT, dual, no distract							
10 car RT, dual, no distract							
11 XRT, dual, distract							
12 car RT, dual, distract							
13 X detect, dual, distract							
14 car detect, dual, distract							

Variable	8	9	10	11	12	13	14
1 Age	.22	.26	.13	.27	.31	.36	.26
2 CS left	-.21	-.34	-.19	-.38	-.39	-.14	-.14
3 CS binocular	-.06	-.25	-.13	-.25	-.27	-.09	-.19
4 Symbol Digit	-.27	-.38	-.25	-.34	-.43	-.39	-.32
5 Spatial Span total	-.24	-.30	-.12	-.26	-.27	-.27	-.08
6 XRT, single	.54	.81	.65	.73	.62	.29	.41
7 car RT, sing, no distract	.62	.53	.56	.46	.43	.09	.29
8 car RT, sing, distract	1.00	.57	.60	.54	.68	.30	.53
9 XRT, dual, no distract		1.00	.57	.80	.64	.40	.34
10 car RT, dual, no distract			1.00	.52	.69	.31	.52
11 XRT, dual, distract				1.00	.61	.41	.25
12 car RT, dual, distract					1.00	.53	.66
13 X detect, dual, distract						1.00	.30
14 car detect, dual, distract							1.00

Note: CS = Contrast sensitivity; XRT = reaction time to the Xs (primary task) on the Computerised Visual Attention Test (CVAT); Car RT = reaction time to cars (secondary task) on the CVAT; sing = single task condition on the CVAT; dual = dual task condition on the CVAT; distract = presence of visual distracters on the car detection task on the CVAT; no distract = no visual distracters on the car detection task on the CVAT; detect = detection errors on the CVAT. Correlations greater than .27 significant at the p<.01 level and those greater than .34 significant at the level of p<.001.

APPENDIX 9

Table 1
Levels of confidence in difficult driving situations, percentages

	Level of confidence				
Driving situation	Not at all	Not very	Reasonably	Very	Completely
In the rain	1.0	3.8	51.0	27.9	16.3
When alone	0.0	0.0	16.3	33.7	50.0
Parallel parking	7.7	24.0	37.5	18.3	12.5
Right turns	1.0	3.8	32.7	31.7	30.8
Freeways	1.0	4.8	25.0	34.6	34.6
High traffic roads	0.0	2.9	31.7	37.5	27.9
Peak hour	0.0	4.8	38.5	32.7	24.0
At night	2.9	11.5	36.5	29.8	19.2
At night in the rain	6.7	17.3	45.2	20.2	10.6

Table 2
Levels of avoidance of difficult driving situations, percentages

	Level of avoidance				
Driving situation	Never	Rarely	Sometimes	Often	Always
In the rain	67.3	19.2	11.5	1.0	1.0
When alone	95.2	4.8	0.0	0.0	0.0
Parallel parking	47.1	16.3	17.3	8.7	10.6
Right turns	71.2	15.4	10.6	1.9	1.0
Freeways	82.7	9.6	2.9	1.0	3.8
High traffic roads	76.9	12.5	9.6	1.0	0.0
Peak hour	68.3	10.6	18.3	2.9	0.0
At night	67.3	13.5	11.5	2.9	4.8
At night in the rain	57.7	18.3	11.5	5.8	6.7

APPENDIX 10

Inter-correlations between candidate predictor variables for a regression procedure predicting overall avoidance of difficult driving situations (n = 104)

Variable	1	2	3	4	5	6	7
1 Age	1.00	.14	.05	.29	.09	.36	.27
2 General health		1.00	.55	-.01	.09	.30	.32
3 Medication use			1.00	-.09	.12	.14	.11
4 Visual acuity, right eye				1.00	-.03	.10	.07
5 car RT, single, no distract					1.00	.46	.29
6 car RT, dual, distract						1.00	.70
7 car detect, dual, distract							1.0

Note: car RT = reaction time to the cars (secondary task) on the Computerised Visual Attention Test (CVAT); car detect = detection errors for cars on the CVAT; single = single task condition on the CVAT; dual = dual task condition on the CVAT. Correlations greater than .24 significant at the $p < .01$ level and those greater than .33 significant at the $p < .001$ level.

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