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).

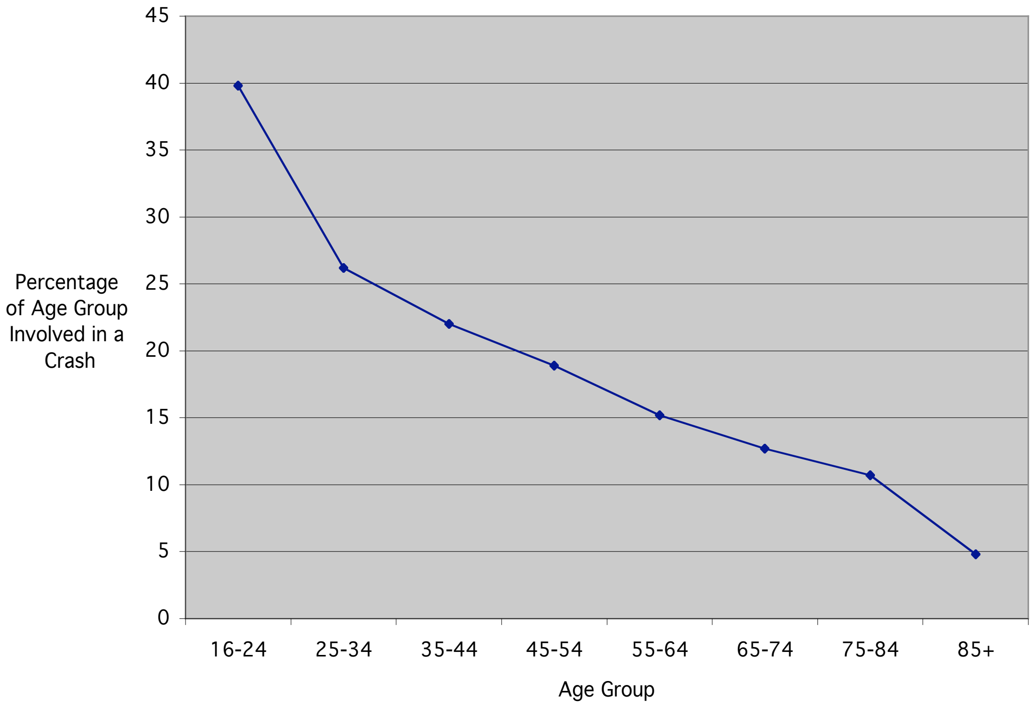

Figure 2.1. Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group

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.)

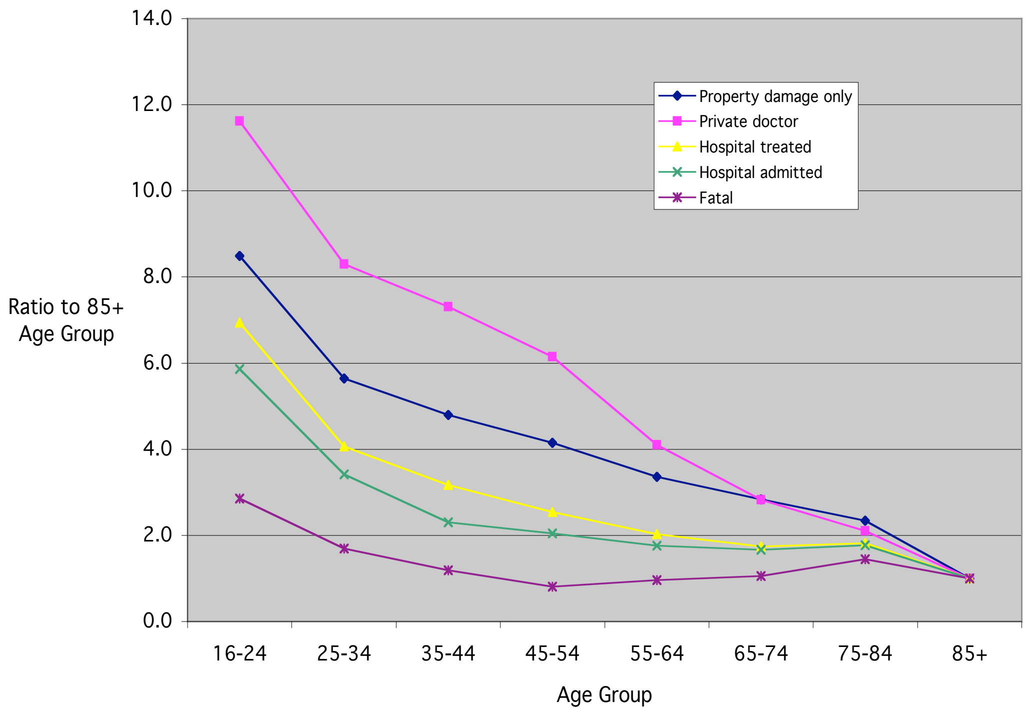

Figure 2.2. Crash-Involved Drivers Per Head of Population in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged Over 84

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.

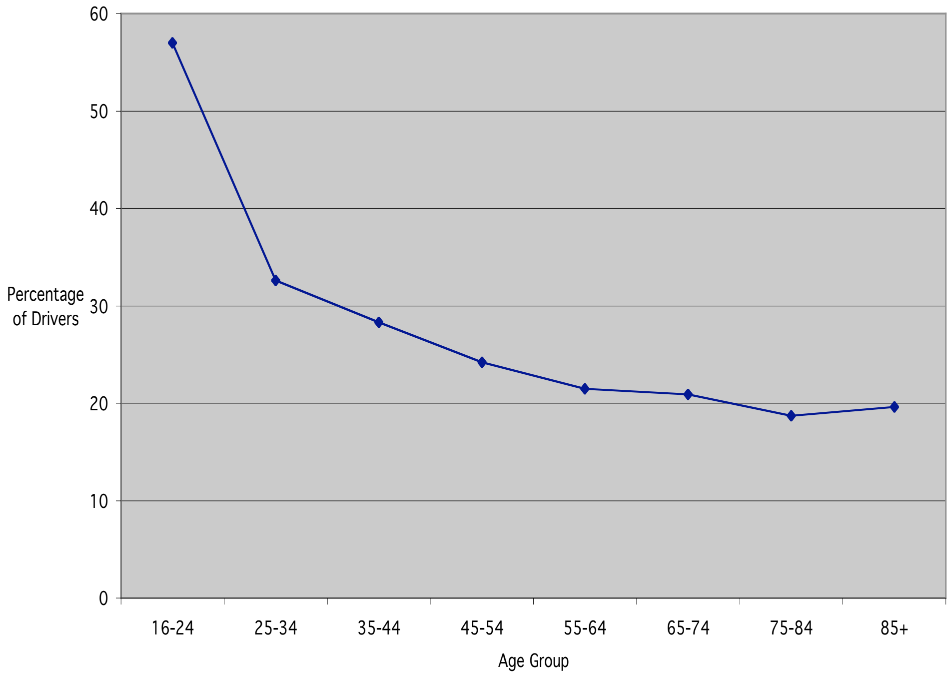

Figure 2.3. Percentage of Licensed Drivers Involved in Crashes in South Australia from 1994 to 1998, by Age Group

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.

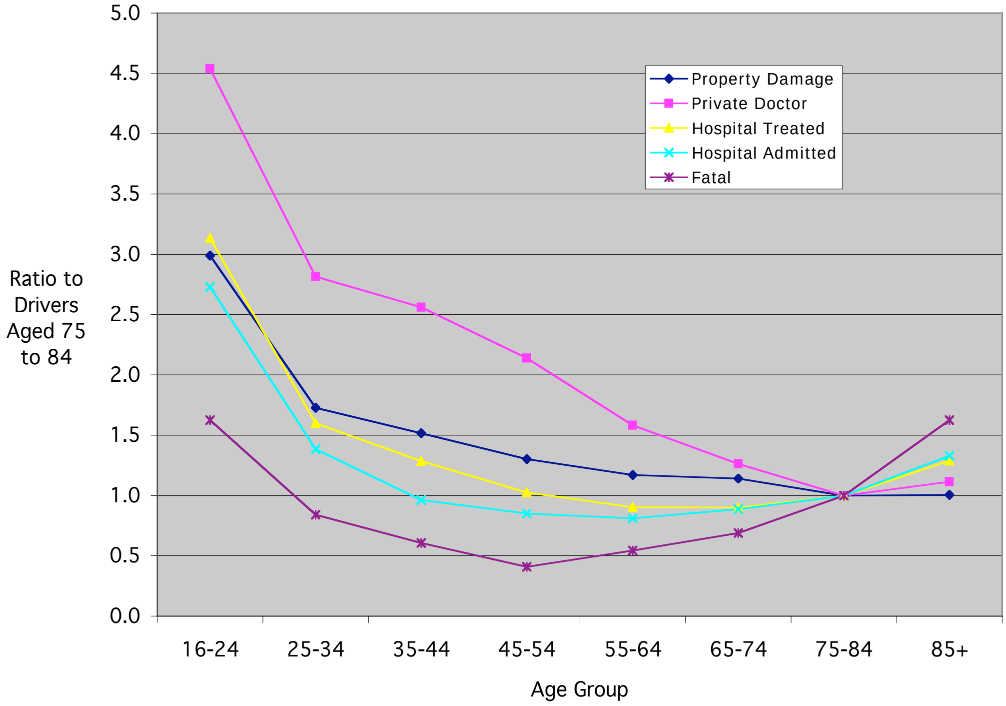

Figure 2.4. Crash-Involved Drivers per Licensed Driver in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 75 to 84

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.

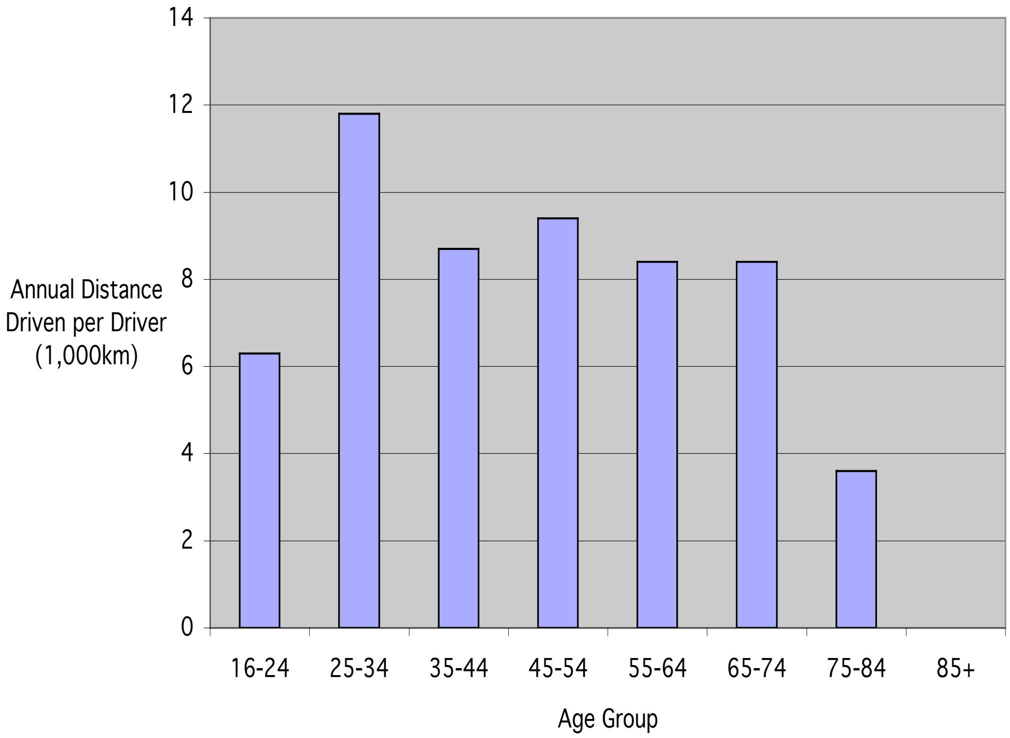

Figure 2.5. Average Kilometres Driven (x 1,000) by Drivers in South Australia in the 12 Months 1997-1998, by Age Group

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.

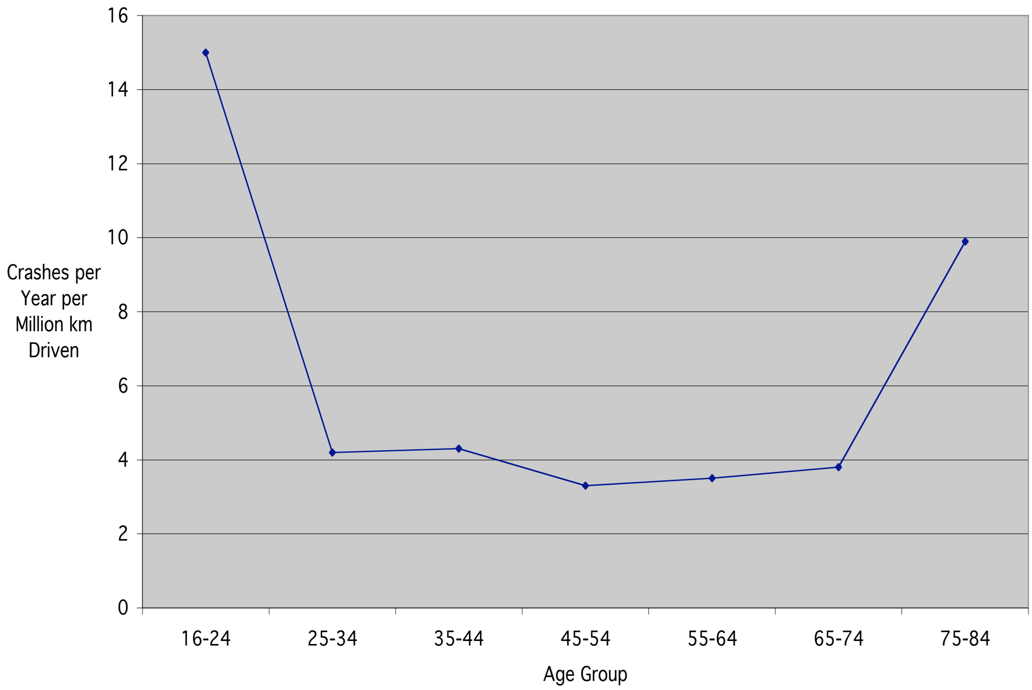

Figure 2.6. Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group

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.

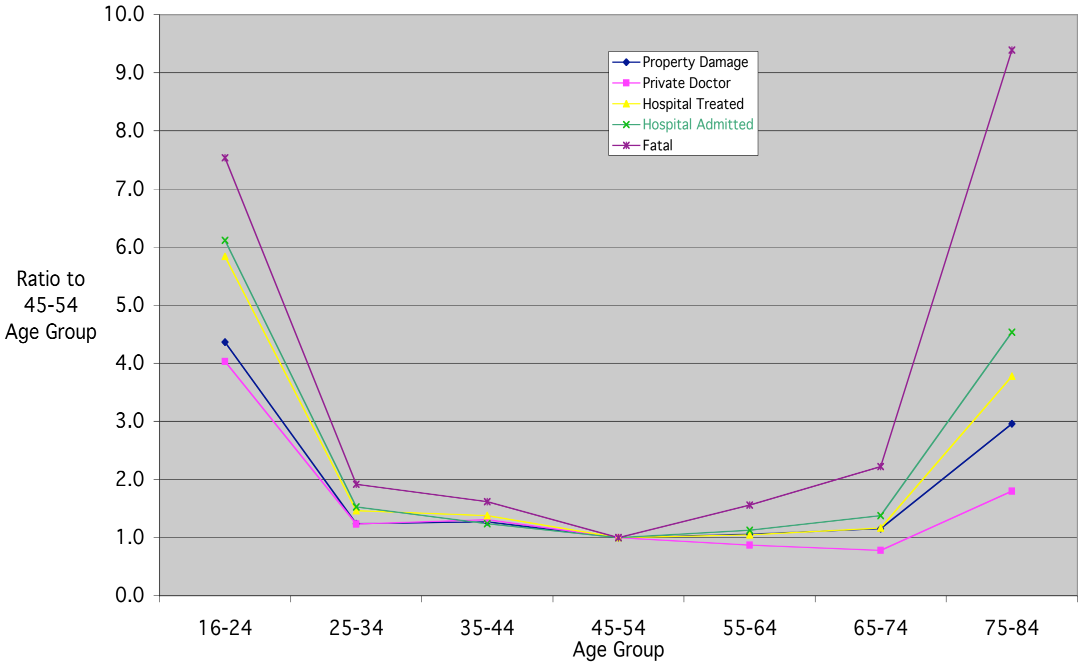

Figure 2.7. Crash-Involved Drivers Per Million Kilometres Driven in South Australia from 1994 to 1998, by Age Group and Crash Injury Severity, Compared to Drivers Aged 45 to 54

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).

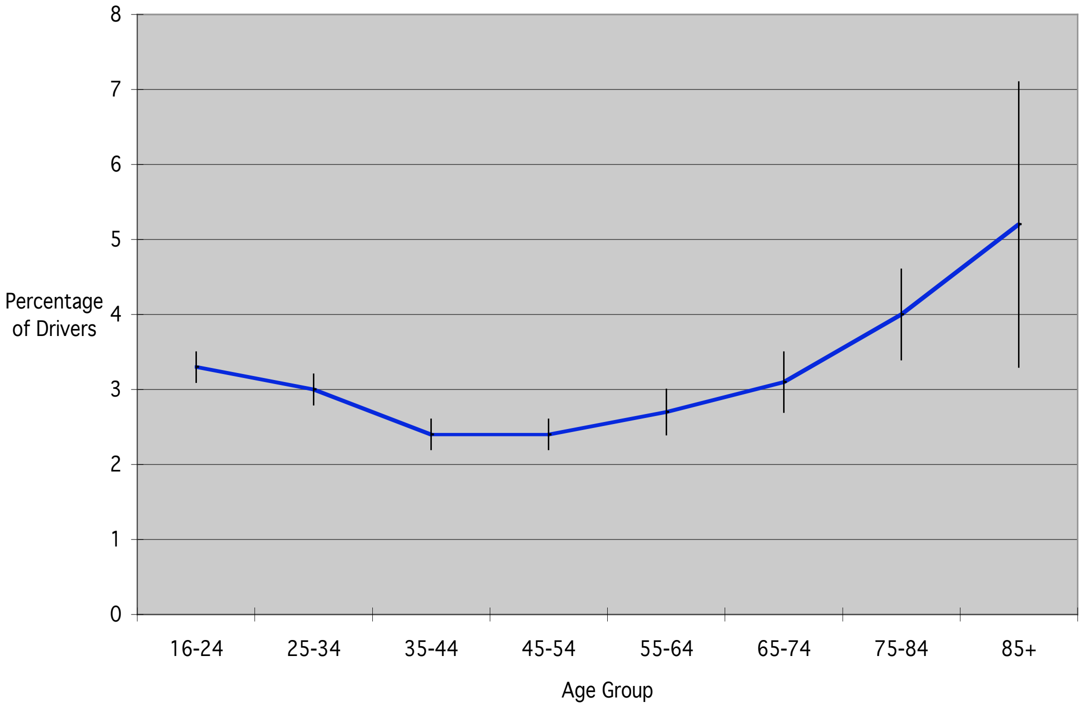

Figure 2.8. Crash-Involved Drivers Whose Crashes Resulted in a Serious or Fatal Injury to One or More Crash Participants in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

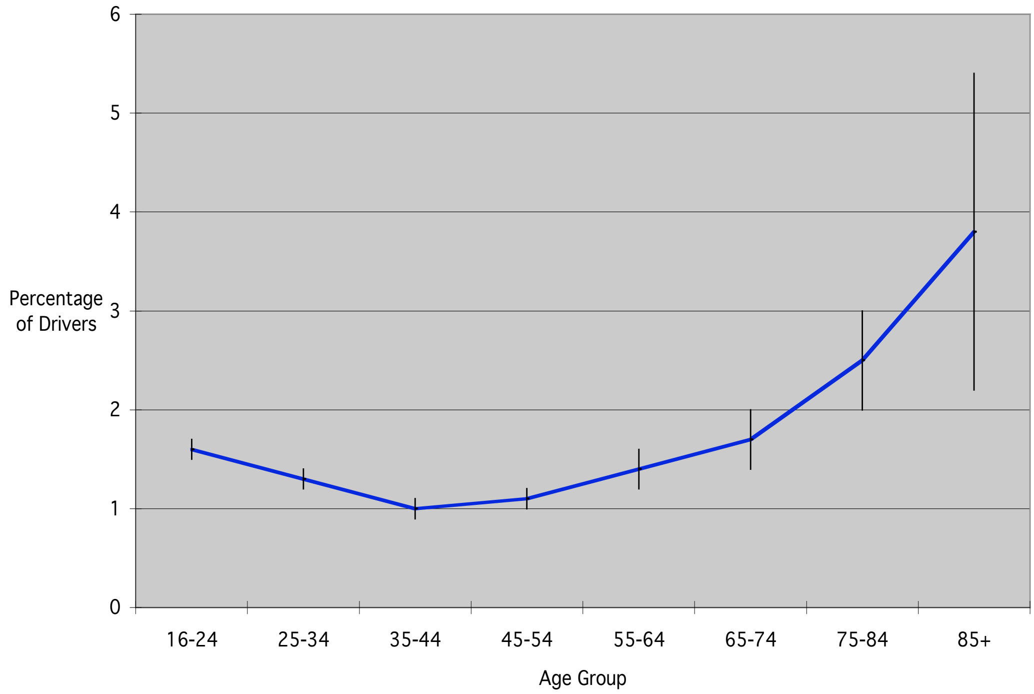

Figure 2.9. Crash-Involved Drivers Who Were Seriously Injured or Killed in the Crash in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

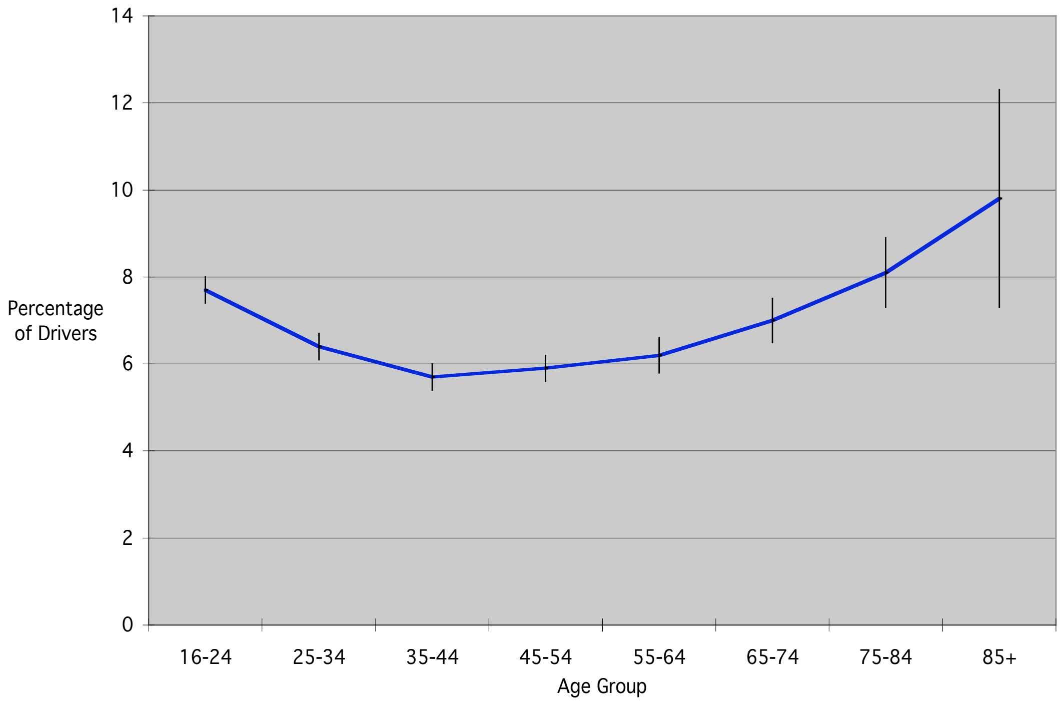

Figure 2.10. Crash-Involved Drivers Who Were Involved in Right Turn Crashes in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

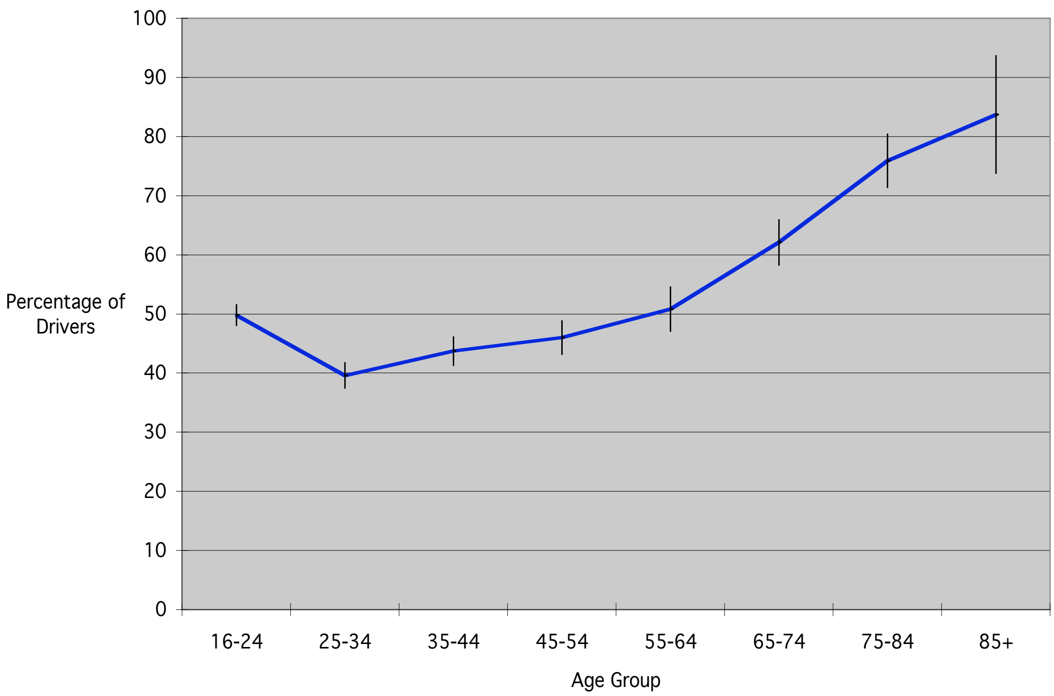

Figure 2.11. Crash-Involved Drivers Who Were Turning Prior to the Crash in South Australia from 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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).

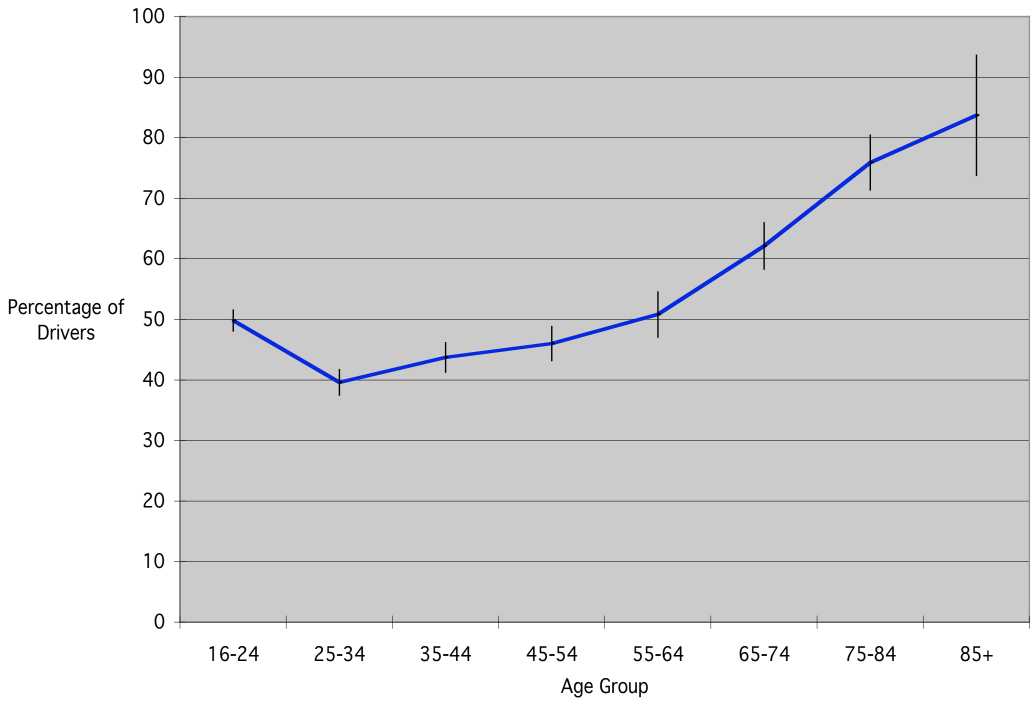

Figure 2.12. Right Turn Crash-Involved Drivers Who Were Turning Right at the Time of the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

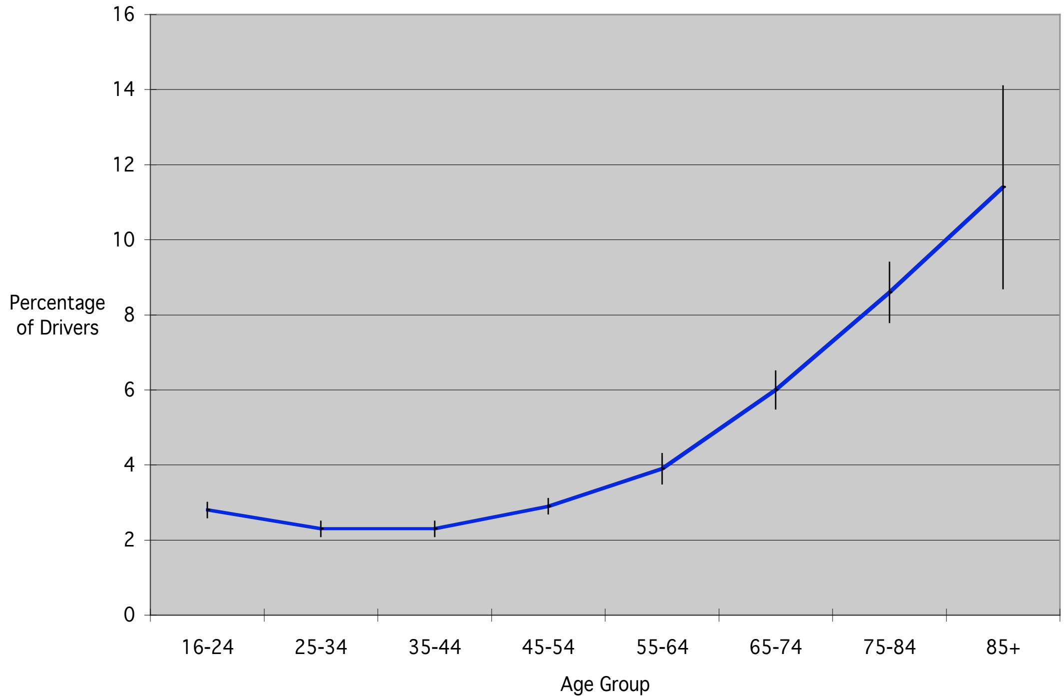

Figure 2.13. Crash-Involved Drivers Who Disobeyed a Traffic Signal, Stop Sign or Give Way Sign in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

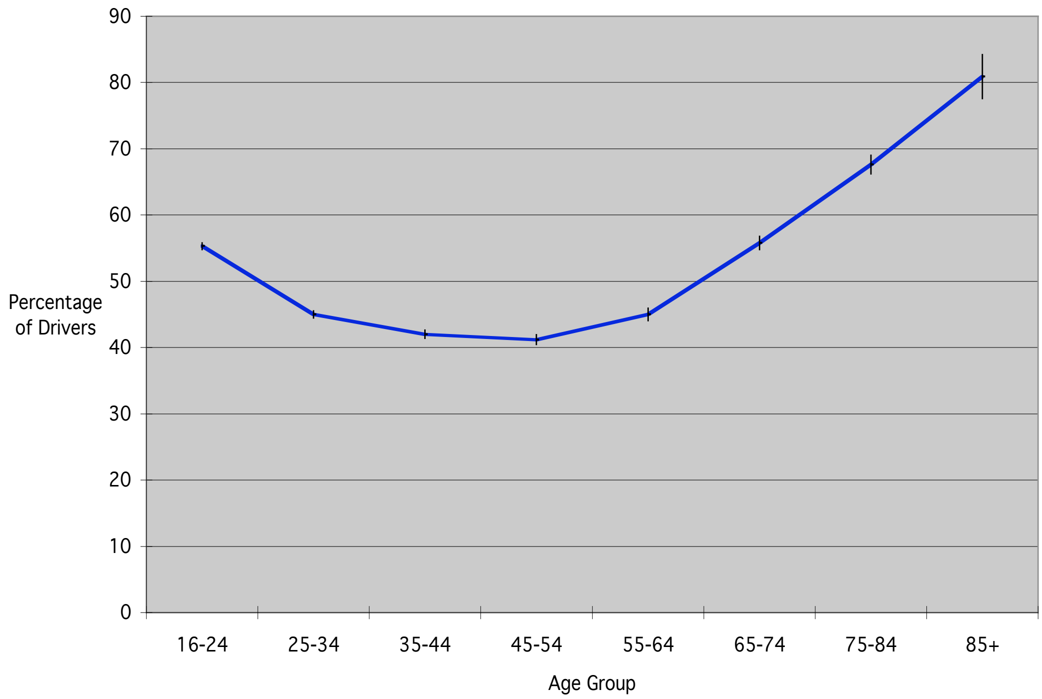

Figure 2.14. Crash-Involved Drivers Deemed to be Responsible for the Crash in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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).

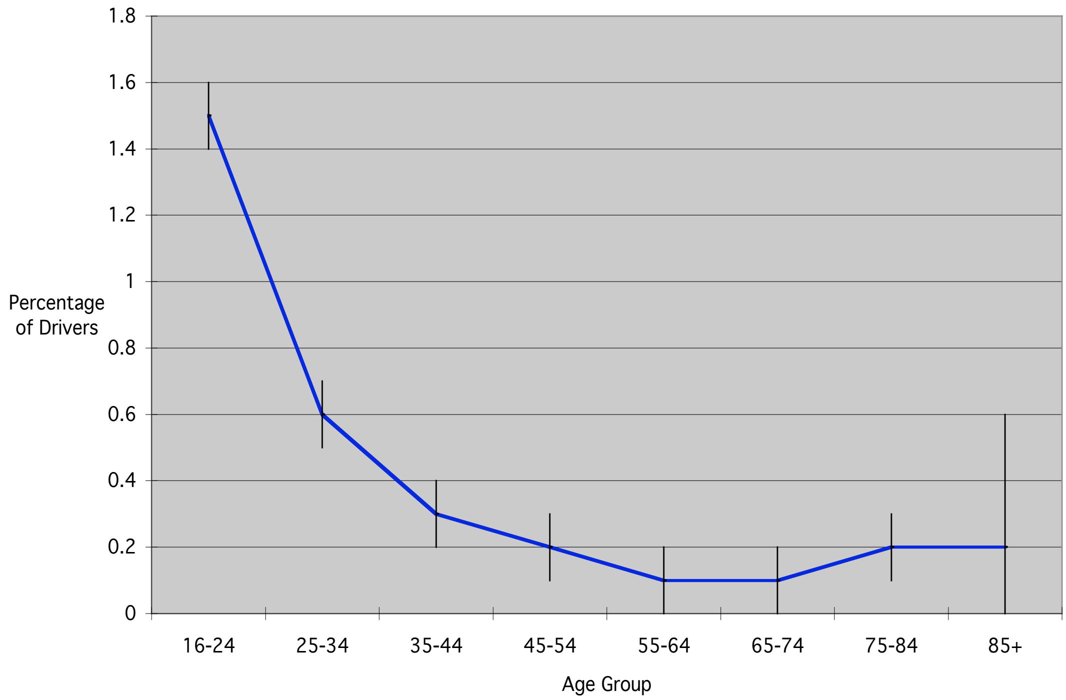

Figure 2.15. Crash-Involved Drivers Deemed to Have Been Driving at Excessive Speed in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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).

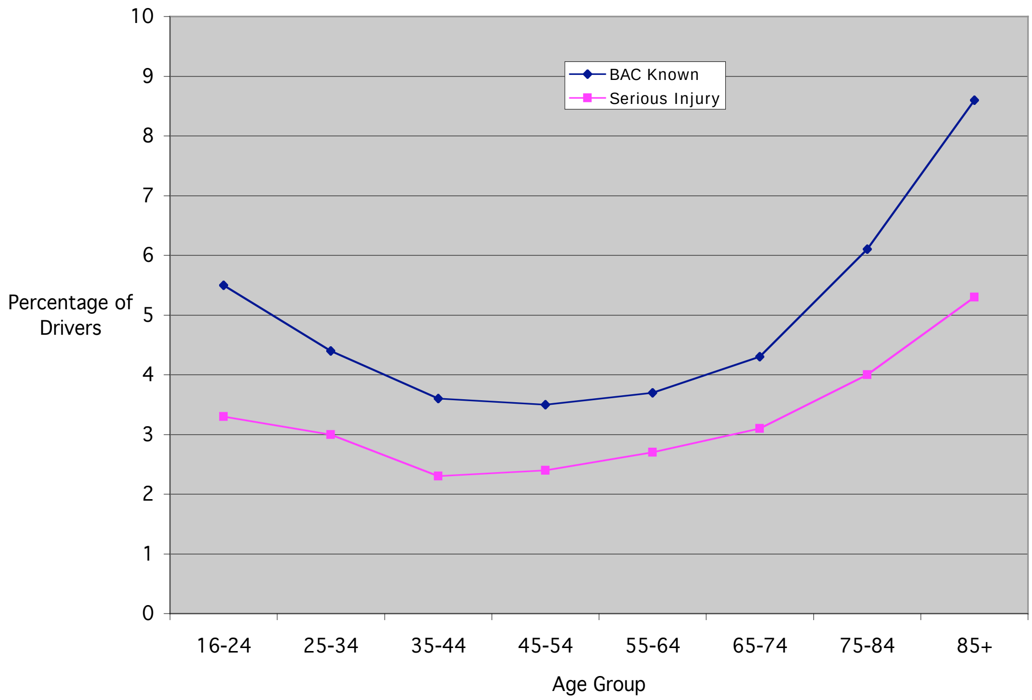

Figure 2.16. Percentage of Crash-Involved Drivers for Whom a Blood Alcohol Concentration was Known and Whose Crashes Produced a Fatal or Serious Injury for One or More Crash Participants in South Australia 1994 to 1998, by Age Group

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.

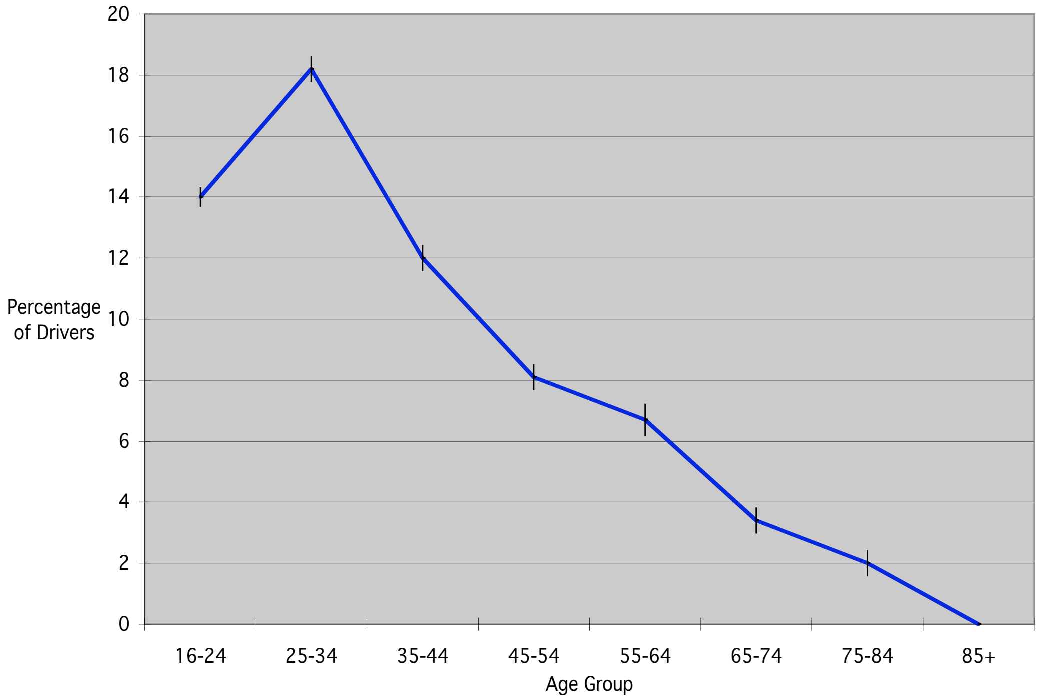

Figure 2.17. Crash-Involved Drivers with a Blood Alcohol Concentration over 0.05 g/L in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

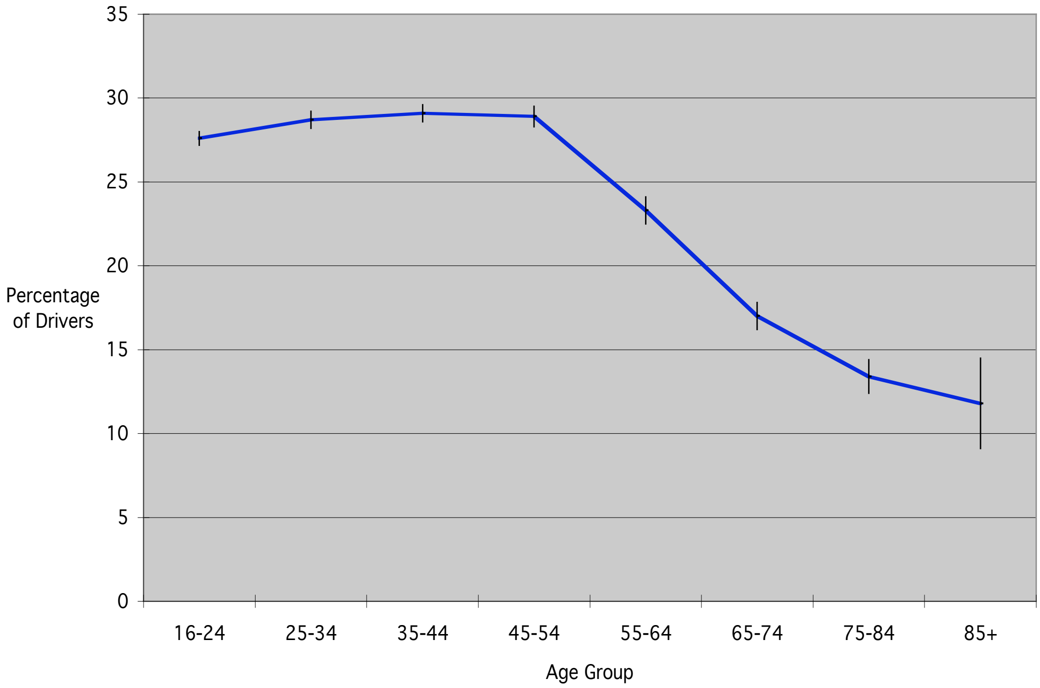

Figure 2.18. Crash-Involved Drivers Who Crashed During Peak Traffic Times in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

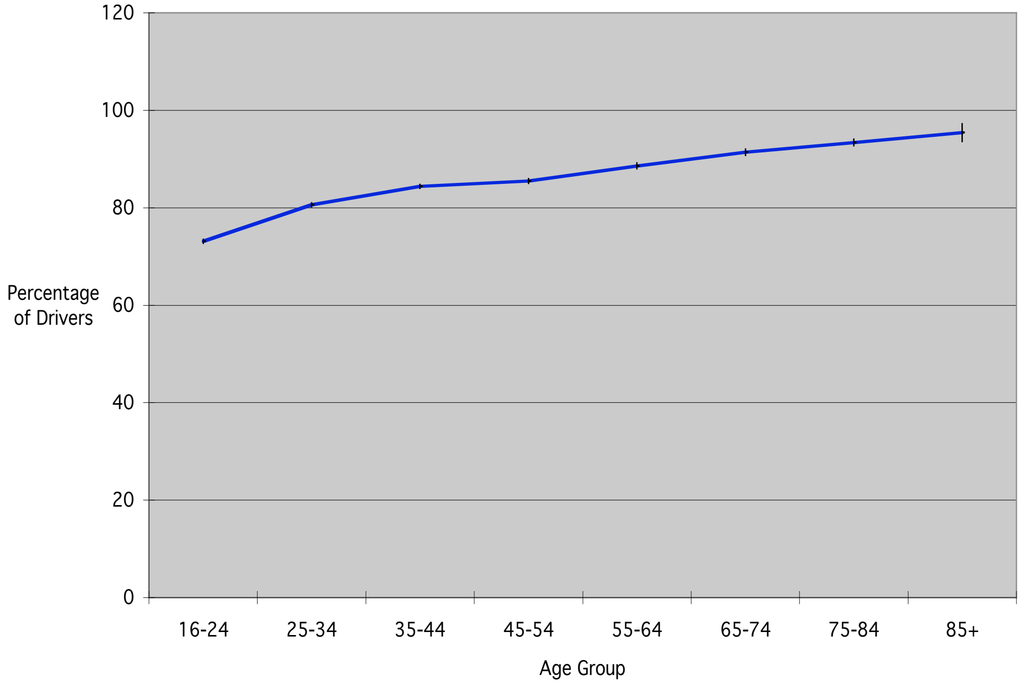

Figure 2.19. Crash-Involved Drivers Who Crashed During Daylight in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Interval*s*

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.

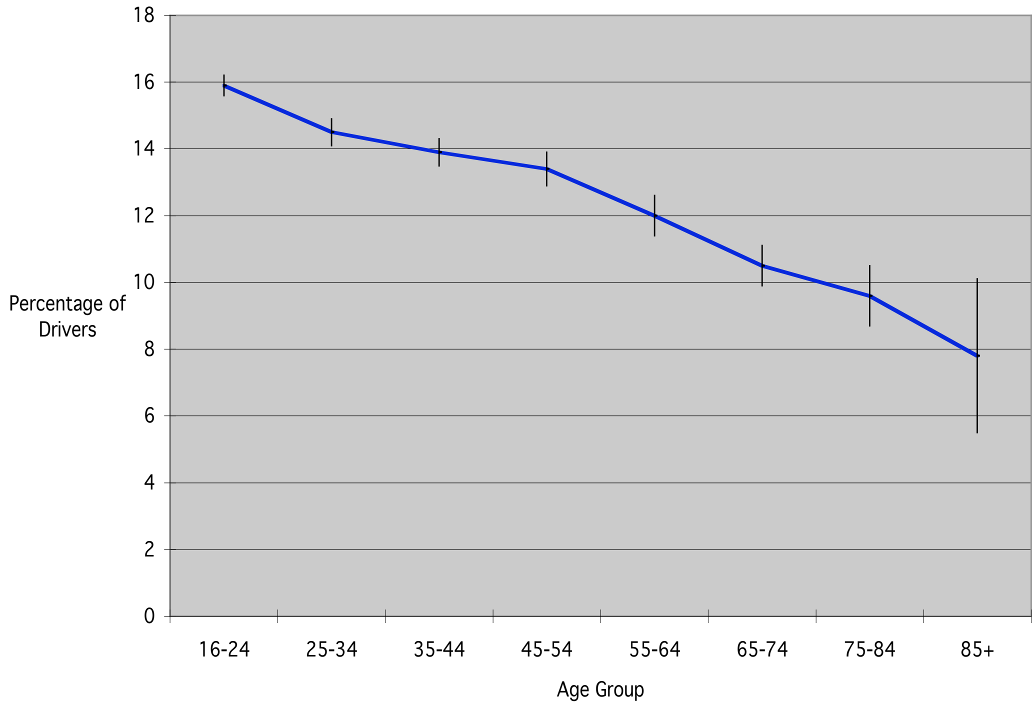

Figure 2.20. Crash-Involved Drivers Who Crashed on Wet Roads in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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.

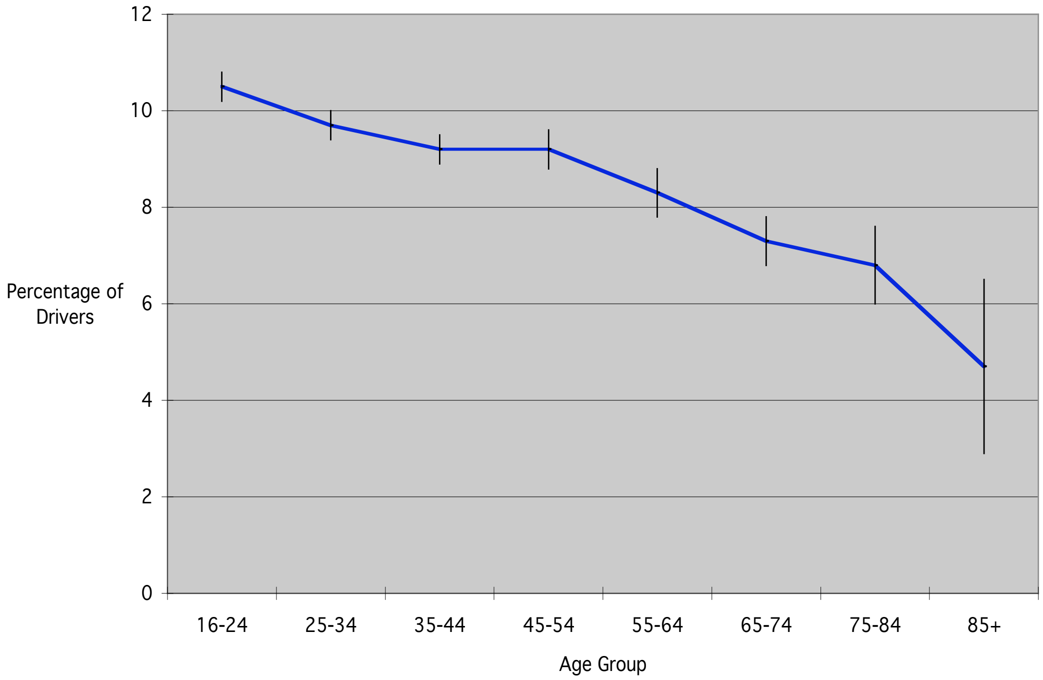

Figure 2.21. Crash-Involved Drivers Who Crashed in the Presence of Rain in South Australia 1994 to 1998, by Age Group, Percentages and 99 Percent Confidence Intervals

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

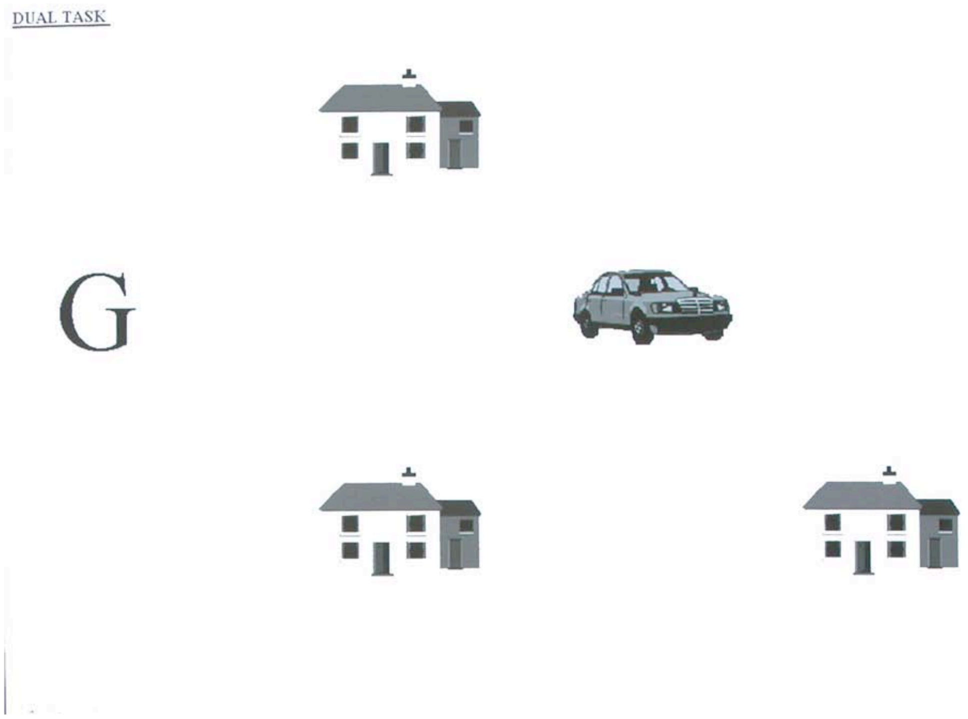

Figure 5.3. Digital photograph of the computer screen during a CVAT subtest requiring divided and selective attention.

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

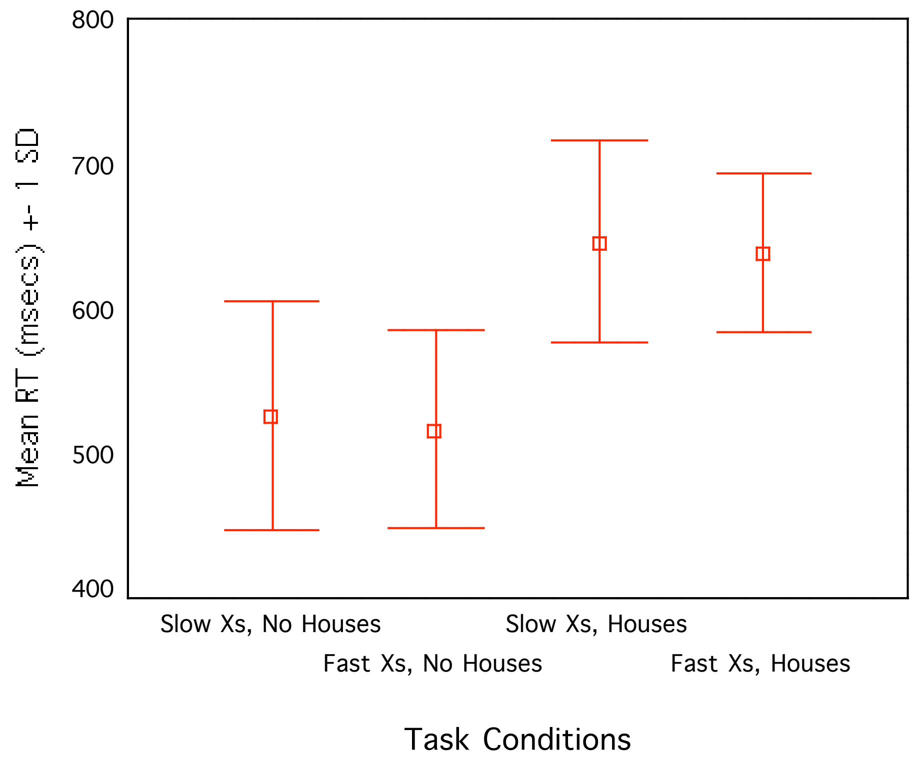

Figure 5.4. Median reaction times for the secondary task (car detection) on the Computerised Visual Attention Test, by task condition.

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

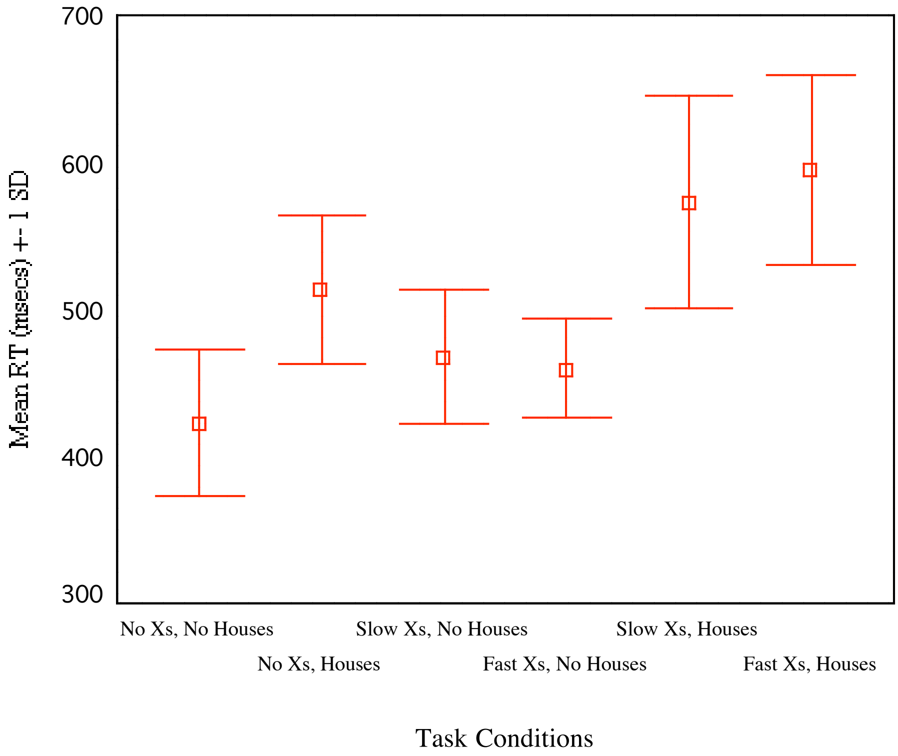

Figure 5.5. Median reaction times for the secondary task (car detection) on the Computerised Visual Attention Test, by task condition

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)