

Road Safety and Mobility of Older Drivers in Rural versus
Urban Areas

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at

The University of Adelaide

Thesis submitted for the degree of Doctor of Philosophy

June 2014

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Abstract

Research indicates that older drivers have an increased risk of being seriously or fatally injured if they crash. However, it is important that older drivers do not cease driving prematurely because driving enables them to remain mobile, which is important for their independence, health and well-being. Older drivers who live in rural or remote areas are of particular interest because the nature of their driving environments may further increase their risk on the road and restrict their mobility. In terms of risk, certain factors that are more common in rural driving environments, such as roads with high speed limits, may contribute to an increased likelihood that older rural drivers will be seriously or fatally injured if they crash, compared to older urban drivers. With respect to mobility, the longer distances that older rural drivers have to travel to reach their destinations, compared to older urban drivers, may restrict their ability to undertake everyday lifestyle activities, particularly those activities that are discretionary in nature (e.g. social activities).

The aim of this thesis was to examine the safety and mobility of older drivers who live in rural areas of South Australia, compared to their urban counterparts. This was achieved through five independent studies. Studies 1 and 2 involved the analysis of crash, serious injury, and fatality data for drivers of different ages from both rural and urban areas of South Australia. Study 1 found that rural drivers aged 75 years and older were more than twice as likely to be involved in crashes that resulted in a serious or fatal injury than urban drivers of the same age. Study 2 found that certain environmental factors - undivided, unsealed, curved and inclined roads, and roads with a speed limit of 100km/h or greater - were more likely to be present in the crashes of older rural drivers than those of older urban drivers and increased the chances that the driver would be seriously or fatally injured. In particular, crashing on a road with a speed limit of 100 km/h or greater produced the largest increase in the risk of serious or fatal injury to the driver.

Study 3 involved an examination of the perceptions of 170 drivers (aged ≥ 75) from rural and urban areas of South Australia regarding: the importance of driving, their access to alternative transportation (e.g. public transport), and the degree to which they self-regulate their driving. It was found that rural participants viewed their driving as being more important than did their urban counterparts and believed that they had fewer alternative transportation options available to them. However, they did not differ on various indices of self-regulation, namely: avoidance of difficult driving situations, reductions in amount of driving and willingness to stop driving. Thus, older rural drivers did not appear to be restricted in their ability to self-regulate because of greater perceived driving importance or limited alternative transportation.

Prior to investigating the driving mobility and exposure of 56 drivers (aged ≥ 75) from rural and urban areas of South Australia, using GPS data loggers and telephone-based travel diaries, the suitability of these methods of data collection was firstly evaluated in Study 4. The participants (who were a sub-sample of the 170 drivers in Study 3) had their driving monitored for a period of one week. Subsequent interviews regarding the data collection process were also undertaken with a subset of 16 participants. It was found that these methods of data collection provided a broad range of accurate information relating to driving exposure (e.g. distance driven, time spent driving, number of trips, travelling speed, road characteristics) and travel patterns (e.g. discretionary and non-discretionary activities, driving routes) for all participants. Furthermore, the participants who were interviewed provided favourable feedback regarding the data collection process.

The data collected for Study 4 were used in Study 5, in order to assess whether older rural drivers are more restricted in their everyday driving mobility, and whether they differ in their exposure to risk while driving, compared to older urban drivers. It was found that, in terms of mobility, rural participants drove further over the week than urban participants, but did not differ in the number of trips that they made or the number that were for discretionary

or non-discretionary activities. With respect to risk-exposure, rural participants were exposed to fewer intersections (potential conflict points) per kilometre¹ and minute driven than urban participants, but drove further and for longer periods on roads with speed limits of 100 km/h or higher and at GPS-measured speeds of 100 km/h or faster.

Overall, the findings suggest that living in rural areas affects the driving safety of older adults, such that the rural driving environment increases the likelihood that they will be seriously or fatally injured in the event of a crash. Importantly, their day-to-day driving mobility is not affected by living in rural areas because they undertake as much driving, and as many activities through their driving, as older urban drivers. Therefore, the challenge for the future is to reduce the risk of serious and fatal injury for older rural drivers without reducing their mobility and, consequently, quality of life in the process. This research does suggest some means by which safe and sustainable mobility may be achieved for older rural drivers, including: modifying the rural driving environment (e.g. decreasing speed limits) and encouraging the use of newer vehicles, which provide better protection in a crash.

¹ Australian/UK English spelling is used throughout this thesis.

Declaration

I, James Thompson, certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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List of Publications

Publications are listed in order of appearance in this dissertation

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2010). *Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010672.pdf>

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013c). An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers. *Accident Analysis and Prevention*, 50, 768-775. doi: 10.1016/j.aap.2012.06.028

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013b). Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation. *Journal of the Australasian College of Road Safety*, 24(1), 30-42. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRSjournalVol24No1Feb13WEBv2.pdf#page=30>

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013a). *The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Brisbane, Queensland. Retrieved from <http://acrs.org.au/files/arsrpe/Paper%20-%20Thompson%20-%20Research%20Methods.pdf>

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2014). *A GPS-based examination of the mobility and exposure to risk of older drivers from rural and urban areas*. Manuscript submitted for publication.

Statements of the Contributions on Jointly Authored Papers

Chapter 3

Title: Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates

Co-Authors: M.R.J., Baldock, J.L., Mathias, L.N., Wundersitz

Contributions: M.R.J. Baldock and I were responsible for the study inception. I was solely responsible for the study design, methodology (which included data extraction, statistical analyses and data interpretation), and manuscript preparation. All three co-authors acted in a supervisory capacity during all stages of this research and manuscript preparation.

Chapter 4

Title: An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers

Co-Authors: M.R.J., Baldock, J.L., Mathias, L.N., Wundersitz

Contributions: M.R.J. Baldock and I were responsible for the study inception. I was solely responsible for the study design, methodology (which included data extraction, statistical analyses and data interpretation), and manuscript preparation. All three co-authors acted in a supervisory capacity during all stages of this research and manuscript preparation.

Chapter 5

Title: Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation

Co-Authors: M.R.J., Baldock, J.L., Mathias, L.N., Wundersitz

Contributions: M.R.J. Baldock and I were responsible for the study inception. I was responsible for the study design, methodology (which included participant recruitment, data

collection, statistical analyses and data interpretation), and manuscript preparation. All three co-authors acted in a supervisory capacity during all stages of this research and manuscript preparation.

Chapter 6

Title: The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently

Co-Authors: M.R.J., Baldock, J.L., Mathias, L.N., Wundersitz

Contributions: M.R.J. Baldock and I were responsible for the study inception. I was responsible for the study design, methodology (which included participant recruitment, data collection, statistical analyses and data interpretation), and manuscript preparation. All three co-authors acted in a supervisory capacity during all stages of this research and manuscript preparation.

Chapter 7

Title: A-GPS based examination of the mobility and exposure to risk of older drivers from rural and urban areas

Co-Authors: M.R.J., Baldock, J.L., Mathias, L.N., Wundersitz

Contributions: M.R.J. Baldock and I were responsible for the study inception. I was responsible for the study design, methodology (which included participant recruitment, data collection, statistical analyses and data interpretation), and manuscript preparation. All three co-authors acted in a supervisory capacity during all stages of this research and manuscript preparation.

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M.R.J. Baldock:  Date: 11/6/2014

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L.N. Wundersitz:  Date: 11/6/2014

Chapter 4

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Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013c). An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers. *Accident Analysis and Prevention*, 50, 768-775.
doi: 10.1016/j.aap.2012.06.028

M.R.J. Baldock:



Date: 11/6/2014

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Date: 11/6/2014

Chapter 5

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Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013b). Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation. *Journal of the Australasian College of Road Safety*, 24(1), 30-42. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRSjournalVol24No1Feb13WEBv2.pdf#page=30>

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Date: 11/6/2014

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M.R.J. Baldock:



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Chapter 7

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Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2014). *A GPS-based examination of the mobility and exposure to risk of older drivers from rural and urban areas*. Manuscript submitted for publication.

M.R.J. Baldock:  Date: 11/6/2014

J.L. Mathias:  Date: 11/6/2014

L.N. Wundersitz:  Date: 11/6/2014

Acknowledgements

I would like to express my sincerest gratitude to the following people, without whom this PhD would not have been possible:

Firstly, to my supervisors for this project, Dr Matthew Baldock, Professor Jane Mathias and Dr Lisa Wundersitz. I cannot thank you enough for being so helpful, supportive and generous with your time. I have been so lucky to have such wonderful people to work with. Not only are you fantastic mentors and colleagues, but also truly inspirational role models and friends.

To my lovely wife and best friend Sarah Streeter. Thank you so much for your love and support. It means so much to me that you always encourage me and are always interested in everything that I do.

To the Royal Automobile Association (RAA) of South Australia. Thank you for generously providing the Road Safety Research Scholarship to me. Without this scholarship I would not have been able to undertake this research. I would also like to thank the RAA staff who were involved in the “Years Ahead” presentations, especially Ben Haythorpe, Belinda Maloney, Anna Woods, Paul Demetriou, David Mitchell and Tony Ey, for allowing me to attend the presentations and recruit participants.

To Professor Mary Lydon, the Director of the Centre for Automotive Safety Research (CASR). I really appreciate the scholarship that was provided by CASR for the final six months of my candidature to help me get my research finished. I am also extremely grateful for all the additional resources that were provided to me throughout my candidature.

To Craig Kloeden from CASR. Thank you for developing the program that was crucial for analysing the GPS data and undertaking this research.

To Jaime Royals and Marleen Sommariva from CASR. Thank you for always being so helpful whenever I needed to find necessary literary resources.

To all the guys who were residents of the “PhD Den” at some stage or another. Your support, as well as all the distractions, made the experience of doing a PhD much more enjoyable.

And finally, to all the men and women who kindly volunteered to participate in this research. Thank you so much for being so friendly and so enthusiastic to help improve the safety and mobility of the older driver community.

Chapter 1: An Introduction to the Issues of Safety and Mobility in Older Drivers

The safety of older drivers is an issue that has been gaining increasing attention over recent years. Researchers, road-safety authorities, policymakers and the general community, alike, are concerned that older drivers may present an increased risk to themselves and to others in terms of adverse driving outcomes (e.g. crash involvement and resulting injury). Questions centre on whether a safety issue genuinely exists and, if so, what can be done in order to address it.

This recent interest in older driver safety has been motivated by the fact that the proportion of older drivers - commonly defined as persons aged 65 years and older - in most western societies will increase significantly in the near future (Burkhardt & McGavock, 1999; Fildes, 2006; Hjorthol, Levin, & Siren, 2010; Langford, 2009; Langford & Koppel, 2006a; OECD, 2001). This is due to several factors. Firstly, the proportion of older people in the population in general is increasing. People are living longer and are much healthier than previous generations. Additionally, the baby boomer generation (born 1946 to 1964), which resulted from the increased birth rates after the end of the Second World War, is now starting to move into the older age bracket. It has been predicted that the proportion of people aged 65 years and older in the member countries of the Organisation for Economic Co-operation and Development (OECD) will double from 13% in the year 2000 to 25% in 2050 (OECD, 2001). Thus, one in every four people in the developed world will be in this age range. In Australia, the number of people aged 65 years and older is expected to more than double between 2000 and 2031 (Booth & Tickle, 2003).

The expected increase in the number of older drivers on the road is also related to the documented increase, with each successive cohort, in the proportion of older people who hold a driver's licence (Hakamies-Blomqvist, 1993; Hjorthol, et al., 2010; Maycock, 1997; Sivak & Schoettle, 2012). This is particularly so for women, with the growth in female licensure

among older drivers exceeding the growth in male licensure (Burkhardt & McGavock, 1999; Hjorthol, et al., 2010; Maycock, 1997; OECD, 2001). People are also increasingly retaining their driving licences and continuing to drive much later into life, as well as driving longer distances, than previous generations (Burkhardt & McGavock, 1999; Fildes, Fitzharris, Charlton, & Pronk, 2001; Hjorthol, et al., 2010; Hu, Jones, Reuscher, Schmoyer Jr, & Truett, 2000; Lyman, Ferguson, Braver, & Williams, 2002; OECD, 2001). In addition, drivers who are now moving into this older age group, or will do so in the future, are more likely to have been driving throughout their lives, and are also likely to be more dependent on their cars and the ability to drive (Collia, Sharp, & Giesbrecht, 2003; Eby & Molnar, 2012; Odell, 2009; OECD, 2001). Consequently, it has been predicted that the proportion of licensed drivers aged 65 and over will increase in the OECD member countries and that, in Australia, there will be a 75% increase from 13% of the population of licensed drivers in the year 2000 to 22% in 2030 (OECD, 2001).

Given this increase in the number of older drivers on the road, there is growing interest in issues relating to the safety of older drivers. However, there has also been increasing recognition of the existence of other issues that have a bearing on policies surrounding ageing and driving. Specifically, there has been a growing awareness that the mobility that driving provides (defined here as access to lifestyle activities) for older persons is important for their health and well-being (Adler, Rottunda, & Kuskowski, 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Edwards, Perkins, Ross, & Reynolds, 2009; Fonda, Wallace, & Herzog, 2001; Langford & Koppel, 2006a; Marottoli et al., 2000; Marottoli et al., 1997; Mezuk & Rebok, 2008). Therefore, despite any potential issues related to their driving safety, it is important that older adults continue to drive for as long as it remains reasonable to do so.

The issues of safety and mobility may be of particular importance in relation to those older drivers who live in rural or remote areas. This is because the circumstances of living in rural areas, with longer distances to travel, increased driving importance, limited alternative

transportation and roads with high speed limits, may both increase the risk of older drivers on the road and restrict their mobility. The overall aim of the current thesis was to examine both the safety and mobility of older drivers who live in rural or remote areas of South Australia, compared to their urban counterparts.

It is first necessary, however, to provide a background to issues relating to the safety of older drivers and the importance of their driving mobility. In regard to the safety of older drivers, this chapter begins with an evaluation of research into their overall crash involvement in order to determine whether, as a group, they pose a greater risk on the road. This is followed by a summary of research that identifies the health, functional and cognitive factors, which decline with age, and are related to a decreased ability to drive and an increased crash risk. Next, this chapter provides an examination of research into the usefulness of mandatory fitness-to-drive assessments as a way to deal with the issue of the safety of older drivers. Then, in order to address the driving-related mobility of older adults, this chapter reviews research that examines the importance of driving to their health and well-being, as well as the consequences of a loss of this mobility through driving cessation. The chapter finishes with an overview of research into the self-regulatory driving practices of older adults. Self-regulation involves individuals voluntarily reducing either the overall amount that they drive or the amount that they drive in difficult conditions (e.g. peak hour traffic) in order to prevent a crash. Self-regulation is important in the context of this research, as it offers a means whereby older drivers can continue to drive and maintain their mobility while also potentially increasing their safety on the road.

Issues Relating to the Safety of Older Drivers

The first section of this chapter provides a background to the main issues relating to the safety of older drivers. It begins with an evaluation of research into their overall crash

involvement. The purpose of this is to determine whether older drivers, as a group, present a risk on the road.

Crash involvement of older drivers.

Total number of crashes.

In order to understand the overall crash involvement of older drivers, it is firstly important to examine the total number of crashes that they are involved in, compared to other age groups. Previous studies (Baldock & McLean, 2005; Lyman, et al., 2002; Ryan, Legge, & Rosman, 1998), which have undertaken such examinations, have demonstrated that older drivers have fewer crashes than drivers in younger age groups. For example, research by Ryan et al. (1998) examined police-reported crashes that occurred in Western Australia (1989 to 1992) and found that crash numbers were highest for drivers in the 20 to 24 year old age group, and then decreased with each successive five-year age group to a minimum for those aged 80 and over. Indeed, drivers below the age of 25 were involved in 35% of police-reported crashes, compared to 3% for drivers aged 70 and older. Similar findings of a low number of crashes involving older drivers compared to drivers in younger age groups have been reported in studies undertaken in South Australia (Baldock & McLean, 2005) and Victoria (Fildes et al., 1994), as well as in the USA (Lyman, et al., 2002) and Europe (OECD, 2001).

Crashes per head of population and per licensed driver.

When comparing the crash involvement of various age groups it is important to note that different age groups have different population numbers and rates of licensure (Baldock & McLean, 2005; Lyman, et al., 2002; Maycock, 1997). Consequently, there may be lower numbers of older driver crashes because there are fewer people in these age groups and, most importantly, fewer licensed drivers. Baldock and McLean (2005) examined the crash

involvement on a per head of population and per licensed driver basis, by age group, using data on police-reported crashes in South Australia (1994 to 1998). They found that crash involvement decreased with successive 10-year age groups after the 16 to 24 year old age group, but that the decreases with age were not as strong when population and licensure differences across groups were taken into account. The findings that older drivers have fewer crashes than younger drivers, even after controlling for decreases with age in population and licensure, have also been replicated by studies in Western Australia (Ryan, et al., 1998), Victoria (Fildes, et al., 1994), the USA (Lyman, et al., 2002; Stutts & Martell, 1992) and Europe (Hakamies-Blomqvist, 2002).

Crashes per distance driven.

It has also been shown that older drivers travel fewer kilometres, on average, than drivers in younger age groups (Baldock & McLean, 2005; Collia, et al., 2003; Li, Braver, & Chen, 2003; Lyman, et al., 2002; Maycock, 1997; Ryan, et al., 1998). Therefore, this difference in driving exposure may further account for the low number of crashes that older drivers are involved in. Indeed, when crash rates per unit of distance driven are calculated for different age groups, studies have demonstrated that younger and older drivers have elevated crash rates, while middle-aged drivers have low rates (Baldock & McLean, 2005; Fildes, et al., 1994; Li, et al., 2003; Lyman, et al., 2002; Ryan, et al., 1998; Stutts & Martell, 1992). Ryan et al. (1998), for example, examined crash rates per kilometre driven by different age groups in Western Australia and found that the rates were similarly low for groups aged between 25 and 74 years, but were high for ages outside of this range. Drivers in the 17 to 19 year old age group had the highest crash rate, followed by those aged 80 and over. Drivers aged 45 to 49 had the lowest rate. This pattern of crash involvement per unit of distance driven by age group has been termed the ‘U-shaped curve’ and has been similarly demonstrated by research in South Australia (Baldock & McLean, 2005) and Victoria (Fildes,

et al., 1994), as well as the USA (Li, et al., 2003; Lyman, et al., 2002; Stutts & Martell, 1992) and Europe (Maycock, 1997).

The common finding - that the distribution by age of crash involvement per kilometre driven follows a ‘U-shaped curve’ - may reflect a general decline in the driving capacity of older adults. A number of researchers, however, have argued that there are other explanations for these findings, including a low-mileage bias, cohort effects, and a fragility bias. These are discussed in the following sections.

The ‘low mileage bias’.

It has been shown that, regardless of age, gender or other demographic characteristics, drivers who travel small distances, on average, are involved in more crashes on a per unit of distance driven basis than those who travel larger distances (Hakamies-Blomqvist, 2002; Hakamies-Blomqvist, Raitanen, & O'Neill, 2002; Janke, 1991; Langford, et al., 2013; Langford, Methorst, & Hakamies-Blomqvist, 2006; Maycock, 1997). Janke (1991) attributed this finding to differences between high and low mileage drivers in terms of the location of their driving. High mileage drivers may be more likely to accumulate much of their mileage on freeways, where lanes that travel in opposite directions are separated, access from other roads is restricted, and crash occurrences are rare on a road-distance basis. In comparison, low mileage drivers may be more likely to drive on local roads that have more potential crash points (e.g. intersections) and greater traffic congestion. The failure to control for different levels of annual mileage, when calculating crash rates, is referred to as the ‘low mileage bias’ (Janke, 1991; Langford, 2009). The low mileage bias may result in the crash rate per unit of distance driven of older drivers being over-estimated because they travel shorter distances, on average, than younger age groups.

Langford, Methorst, et al. (2006) have calculated crash rates per million kilometres driven for different age groups using Dutch survey data. They found that, once the age groups

were matched for yearly driving distance, the majority of older drivers (aged 75 years and older) were safer than drivers in younger age groups. Only those older drivers with a low mileage (less than 3000 km per year; which amounted to just over 10% of older drivers in the survey) had a relatively high crash rate. These same findings have been replicated by research in Finland (Hakamies-Blomqvist, et al., 2002) and Spain (Alvarez & Fierro, 2008). Hakamies-Blomqvist et al. (2002) suggested that “these findings thus cast serious doubt on any previous reports of age differences in accident risk per distance driven” (p. 274). However, the studies by Langford, Methorst, et al. (2006), Hakamies-Blomqvist et al. (2002), and Alvarez and Fierro (2008) were all based on self-reported crash involvement and driving distances. While research has previously demonstrated consistency between self-reported and official crash data (Begg, Langley, & Williams, 1999; Marottoli, Cooney, & Tinetti, 1997; McGwin Jr, Owsley, & Ball, 1998), self-reported distance driven can be quite divergent from the true amount (Blanchard, Myers, & Porter, 2010; Huebner, Porter, & Marshall, 2006; Staplin, Gish, & Joyce, 2008). Thus, Staplin et al. (2008) have suggested that poor estimation of distance driven could have had an effect on the earlier findings regarding low mileage bias (e.g. Langford, Methorst, et al. (2006)), and emphasised the need for objective exposure measures in future analyses.

Cohort effects on crash involvement.

Another factor that may account for the overrepresentation of older drivers in crash rates per distance driven is the cross-sectional nature of the research on which these findings are often based (Baldock & McLean, 2005). Such research does not take into consideration the differences between drivers born in different times. For example, older cohorts may have had an elevated crash risk even at a younger age. Indeed, longitudinal research has indicated that earlier cohorts of older drivers had higher rates of crash involvement than more recent cohorts (Dellinger, Langlois, & Li, 2002; Evans, 1993; Li, Shahpar, Grabowski, & Baker,

2001; Lyman, et al., 2002; Stamatiadis & Deacon, 1995; Stutts & Martell, 1992). The differences between cohorts that affect their crash risk are likely to be related to driving experience (Maycock, 1997; Stamatiadis & Deacon, 1995). For example, drivers in more recent cohorts typically start driving in early adulthood, while those in older cohorts may have started driving at a much older age, often without needing to pass a comprehensive on-road assessment of their driving in order to obtain a driver's licence. Research by Stamatiadis and Deacon (1995) has demonstrated that cohort effects on the crash involvement of older drivers do exist, but that the effects may be small relative to time-related effects, such as aging. Moreover, they suggested that, despite expected reductions in crash involvement for future cohorts, older drivers will continue to be a high-risk section of the future driving population.

The 'fragility bias'.

A final explanation for the overrepresentation of older adults in reported casualty crashes is that their tolerance to injury is lower than that of younger adults (Evans, 1988; Li, et al., 2003; Viano, Culver, Evans, & Frick, 1990; Viano, King, Melvin, & Weber, 1989). The increased vulnerability of older drivers to injury, also commonly referred to as their 'fragility'², may result in a larger share of their crashes leading to serious or fatal injury and, therefore, being reported to police. Consequently, it is more likely that their crashes will be counted in road crash databases (Hakamies-Blomqvist, 1998, 2002). This may contribute to an apparent overrepresentation in crashes (Langford, 2009). In particular, this may affect crash databases and research studies that use injury as a criterion for inclusion.

Numerous previous studies have, indeed, demonstrated that older drivers are at an increased risk of being seriously or fatally injured when they are involved in crashes

² The term 'frailty' is sometimes used in the literature instead of 'fragility' to describe the likelihood that older adults will sustain an increased level of injury from a crash. However, 'frailty' refers to the ability to subsequently recover from injury. While both terms are relevant to the injury consequences of a crash, discussion of a 'bias' that leads to a larger share of crashes being reported primarily refers to initial injury. Therefore, 'fragility' is used throughout this thesis so that it is consistent with the correct definition.

(Baldock, 2004; Brand et al., 2012; Evans, 2000, 2001; Fildes, et al., 1994; Hanrahan, Layde, Zhu, Guse, & Hargarten, 2009; Kahane, 2013; Langford & Koppel, 2006a; Meuleners, Harding, Lee, & Legge, 2006; Newgard, 2008; OECD, 2001; Rakotonirainy, Steinhardt, Delhomme, Darvell, & Schramm, 2012; Ryan, et al., 1998). A study by Hanrahan et al. (2009) in the USA found that older age was strongly associated with the risk of severe or fatal injuries for drivers involved in motor vehicle crashes. Indeed, drivers aged 85 years and older were at the greatest risk: being over five times more likely than those aged 25-44 years to suffer a moderate injury, over four times more likely to suffer a severe injury, and over ten times more likely to suffer a fatal injury. In Queensland, Australia, a study by Rakotonirainy (2012) similarly found that drivers aged 60 years and over had a higher risk of fatality and crashes resulting in hospitalisation than drivers under the age of 60, and that those aged 80 years and over had the highest risk.

Furthermore, research has attempted to determine the effect that the increased fragility of older adults has on their reportedly higher crash rates. For example, Evans (2000) corrected for the fragility bias by examining the involvement of different age groups in crashes of similar severity (i.e. only those of sufficient severity to have a high likelihood of killing an 80-year old male driver). When these crashes were examined on a per distance basis, it was found that the increase in crash rates with older age was much less than when the fragility bias was not accounted for. Similarly, research by Li, Braver, and Chen (2003) investigated whether the greater involvement of older drivers in fatal crashes per distance driven was caused by their fragility or a high crash rate, in general. It was found that fragility accounted for around 60 to 95% of the excess fatality rates per distance driven. In contrast, research by Dellinger et al. (2002) examined the extent to which the fatal crash involvement of older drivers was determined by their increased risk of fatality when involved in a crash, their increased risk of being involved in a crash, or their level of driving exposure. They found that risk of crash involvement and level of driving exposure made the strongest contributions to

their increased risk of fatal crashes, while risk of fatality when involved in a crash had the smallest influence. Thus, based on the findings of these various studies, it appears that the fragility bias does contribute to an overrepresentation of older drivers in crash rates, but does not account for all of their increased risk.

Older driver crash involvement in the next 20 years.

Given that the amount of older drivers on the road is expected to increase in the next 20 to 40 years, it has also been predicted that the number of crashes involving older drivers will increase (Fildes, et al., 2001; Hu, et al., 2000; Lyman, et al., 2002). Indeed, research by Lyman et al. (2002) provided projections of crash rates in the USA for 2010, 2020 and 2030. This study estimated that, between 1999 and 2030, crash involvement by drivers aged 65 and older may increase by 178% and fatal crash involvement may increase by 155%. Older drivers accounted for 8% of police-reported crashes in 1999, but it was predicted that this would rise to 16% by 2030. It was also predicted that the proportion of fatal crashes that they account for would rise from 14% in 1999 to 25% in 2030. In Australia, a study by Fildes et al. (2001) estimated a 286% increase in fatal crash involvement for older drivers between 1995 and 2025.

However, recent research has indicated that the number of fatal crashes involving older drivers has not increased to the levels predicted by Lyman et al. (2002) and Fildes et al. (2001). For example, research from the USA by Mullen, Dubois, and Bédard (2013) examined crash data from 1975 to 2008 and identified a recent decline in the number of fatal crashes involving older adults despite their increasing number and exposure. Mullen et al. (2013) suggested that the recent decline could be due to the success of road safety initiatives. Other studies from the USA (Cheung & McCartt, 2011; Cheung, McCartt, & Braitman, 2008; Cicchino & McCartt, 2014) have demonstrated that the rates of crash involvement for older drivers (in terms of fatal injury, non-fatal injury and property-damage-only crashes) were also

declining. Indeed, Cheung and McCartt (2011) found that, on a per licensed driver basis, the 37% decline in fatal crashes for older drivers (aged 70 years and older) far exceeded the 23% decrease for middle-aged drivers (aged between 35 and 54 years). This study concluded that the greater declines in the fatality risk of older drivers reflected decreases in both the likelihood of crashing and the likelihood of dying in the crashes that occurred.

Types of crashes.

It is also important to understand the types of crashes that older drivers are more commonly involved in. Past studies from both Australia and other countries have demonstrated that older drivers are overrepresented in:

- multiple vehicle crashes at both uncontrolled and sign-controlled intersections (Braitman, Kirley, Ferguson, & Chaudhary, 2007; Clark, Ward, Bartle, & Truman, 2010; Cooper, 1990; Daigneault, Joly, & Frigon, 2002b; Fildes, et al., 1994; Hakamies-Blomqvist, 1993; Langford & Koppel, 2006b; Maycock, 1997; Mayhew, Simpson, & Ferguson, 2006; McGwin Jr & Brown, 1999; OECD, 2001; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Rakotonirainy, et al., 2012; Ryan, et al., 1998; Stamatiadis, Taylor, & McKelvey, 1991; Viano, et al., 1990; Zhang, Fraser, Lindsay, Clarke, & Mao, 1998),
- crashes in which they were undertaking turning manoeuvres, particularly when turning across oncoming traffic (Cooper, 1990; Daigneault, et al., 2002b; Langford & Koppel, 2006b; Preusser, et al., 1998; Ryan, et al., 1998),
- crashes in which they disobeyed traffic signs or signals (Cooper, 1990; Mayhew, et al., 2006; Preusser, et al., 1998),
- crashes in which they failed to give way to other traffic (Braitman, et al., 2007; Clark, et al., 2010; Cooper, 1990; Mayhew, et al., 2006; McGwin Jr & Brown, 1999;

Preusser, et al., 1998; Rakotonirainy, et al., 2012; Stamatiadis, et al., 1991; Zhang, et al., 1998),

- crashes at day time rather than night time (Catchpole, Styles, Pyta, & Imberger, 2005; Cooper, 1990; Fildes, et al., 1994; Hakamies-Blomqvist, 1994; Mayhew, et al., 2006; McGwin Jr & Brown, 1999; OECD, 2001; Preusser, et al., 1998; Ryan, et al., 1998; Stutts & Martell, 1992; Zhang, et al., 1998), and
- crashes on weekdays rather than weekends (Stutts & Martell, 1992; Zhang, et al., 1998).

Research has attempted to explain why older drivers are overrepresented in crashes at intersections and crashes where they were undertaking turning manoeuvres, disobeyed traffic signs or signals, or failed to give way to other traffic. The most common explanation is that the cognitive and sensory abilities that are needed in order to negotiate these driving situations successfully may decline with age. As a result of this decline, older drivers may be more likely to make errors in these situations (Langford, 2009). In particular, it has been suggested that a decline in divided attention - the ability to attend to multiple stimuli at once - may contribute to crashes by older drivers at intersections and in other similar situations (Dotzauer, Caljouw, de Waard, & Brouwer, 2013; Hakamies-Blomqvist, 1993; OECD, 2001; Preusser, et al., 1998; Romoser, Pollatsek, Fisher, & Williams, 2013). For example, Preusser et al. (1998) suggested that a decline in divided attention may mean that older drivers need more time than younger drivers to make decisions in complex driving situations, but that intersections force them to make decisions under time pressure, while dealing with a cluttered visual array involving threats coming from the periphery (e.g. traffic signals, cars, pedestrians).

Age-related declines in other abilities may also contribute to crashes by older drivers at intersections. Larsen and Kines (2002) conducted an in-depth investigation of left-turn³ crashes by drivers over the age of 74 in Denmark. This study indicated that, as well as poorer attention, the failure to detect approaching road users, miss-judgements of the time necessary to make a turn, and miss-judgements of the distance and speed of other road users, were all involved in these types of collisions. Similarly, research by McGwin Jr and Brown (1999) suggested that perceptual problems and difficulty judging and responding to traffic flow are involved in the crashes of older drivers.

The higher likelihood that older drivers will crash at day time rather than night time, as well as on weekdays rather than weekends, is likely to reflect a greater flexibility to choose when they do their driving. This is because many older drivers are retired and are able to choose not to drive in difficult conditions (Cooper, 1990; Maycock, 1997). Consistent with this explanation, older drivers have also been shown to be less likely than younger drivers to crash during peak hour (Cooper, 1990; OECD, 2001) and in inclement weather (Daigneault, et al., 2002b; Hakamies-Blomqvist, 1994; McGwin Jr & Brown, 1999; OECD, 2001).

However, despite being more likely than younger drivers to be involved in certain types of crashes, they are less likely to be involved in other types. Most notably, they are less likely to be involved in crashes in which they were driving at excessive speed (Maycock, 1997; NHTSA, 2013b; OECD, 2001; Rakotonirainy, et al., 2012) or with an illegal blood alcohol concentration (Catchpole, et al., 2005; Hakamies-Blomqvist, 1994; Maycock, 1997; Mayhew, et al., 2006; Rakotonirainy, et al., 2012). This suggests that they are less likely to make deliberate decisions that result in unsafe driving.

³ Comparable to right-turn in Australia.

Crash responsibility.

It has also been shown that older drivers are more likely than younger drivers to be responsible for the crashes in which they are involved (Cooper, 1990; Cooper, Tallman, Tuokko, & Beattie, 1993a; Elliott, Elliott, & Lysaght, 1995; Hakamies-Blomqvist, 1993; Langford, Koppel, Andrea, & Fildes, 2006; Maycock, 1997; Mayhew, et al., 2006; McGwin Jr & Brown, 1999; Preusser, et al., 1998; Rakotonirainy, et al., 2012; Stamatiadis & Deacon, 1995; Verhagen, 1995; Viano, et al., 1990). For example, research in Tasmania (Australia) by Langford, Koppel, et al. (2006) linked police records and insurance claims in order to compare middle-aged (41 to 55 years) and older drivers (65 years and older) in terms of assessments of the responsibility for their crashes. It was found that the older drivers were 1.5 times more likely to be judged by both sources to be responsible for their crashes than middle-aged drivers.

The finding relating to crash responsibility has, however, been questioned. For example, it has been suggested that the over-involvement of older drivers in crashes in which they are deemed responsible may be due to their being involved in fewer crashes as the non-responsible party (Hakamies-Blomqvist, 2002). This is because their driving style is slow, cautious and defensive. Therefore, when a driver of another vehicle makes a mistake that could potentially lead to a collision with an older driver, both the older driver and the other driver have more time to avoid the collision. Consequently, the proportion of the crashes of older drivers in which they are in error may be larger due to their lower likelihood of being in crashes in which they are not at fault rather than a greater tendency of making errors that lead to crashes. Another explanation is that authorities may be biased against older drivers when making assessments of responsibility for crashes (Hakamies-Blomqvist, 1993). Moreover, the study by Langford, Koppel, et al. (2006) estimated that, had older drivers' responsibility for crashes been the same as that of middle-aged drivers, the reduction in all casualty crashes would have been only 3.5%. As a result, Langford, Koppel, et al. concluded that the increased

responsibility for crashes on the part of older drivers only makes a small contribution to the overall level of road trauma, although this may rise with the predicted increase in the numbers of older drivers on the road in the next few decades.

Summary of the crash involvement of older drivers.

To summarise, older drivers have fewer total crashes than drivers in younger age groups and have fewer crashes even after controlling for decreases with age in population numbers and rates of licensure (Baldock & McLean, 2005; Lyman, et al., 2002; Ryan, Legge, & Rosman, 1998). However, they have an elevated crash risk on a per unit of distance driven basis (Baldock & McLean, 2005; Li, et al., 2003; Lyman, et al., 2002; Ryan, et al., 1998). There are several factors, however, that may explain this finding. Firstly, older drivers travel shorter distances, on average, than younger drivers (Baldock & McLean, 2005; Ryan, et al., 1998) and may therefore undertake most of their driving on local roads that have more potential crash points (Janke, 1991). This may lead to an over-estimation of their crash involvement per distance driven and is referred to as the ‘low mileage bias’ (Janke, 1991; Langford, 2009). Secondly, cross-sectional research which compares the crash rates of older and younger drivers may not account for differences between drivers born in different times (Baldock & McLean, 2005). For example, older cohorts may have had an elevated crash risk even at a younger age and this may contribute to an over-estimation of older driver crashes (Baldock & McLean, 2005; Stamatiadis & Deacon, 1995). Thirdly, older drivers are more likely to be seriously or fatally injured in a crash (Baldock & McLean, 2005; Rakotonirainy, et al., 2012; Ryan, et al., 1998) making it more likely that their crashes will be counted in road crash databases (Hakamies-Blomqvist, 1998, 2002). This ‘fragility bias’ may also contribute to an apparent overrepresentation in crashes (Langford, 2009).

Moreover, it has been suggested that total crash involvement and crash involvement per licensed driver are the most meaningful rates (Baldock & McLean, 2005; Maycock, 1997)

to consider. As Baldock and McLean (2005) have stated “the former indicates the extent to which the age group contributes to a jurisdiction’s crash numbers, while the latter indicates the risk associated with granting a licence to a typical member of the age group” (p. 11). Therefore, judging by these measures alone, it appears that, overall, older drivers are involved in fewer crashes than younger age groups and, consequently, do not pose a risk on the road.

However, although the fragility bias is offered as a reason to doubt claims of an increased older driver crash rate it is, in itself, a valid basis for concern regarding older driver safety. Langford and Koppel (2006a) have suggested that “relative to other drivers, they are more likely to be their own victims, largely because of this factor (fragility)” (p.358). Indeed, Maycock (1997) has suggested that the greater susceptibility of older drivers to injury justifies the attention given to them. It also justifies the need to both reduce the amount of crashes that they are involved in and provide better protection for them when they do crash. This is particularly so, given that, with the predicted increase in the amount of older drivers on the road in the next 20 to 40 years, the number of crashes that they are involved may also increase (Fildes, et al., 2001; Lyman, et al., 2002).

As well as their high risk of serious or fatal injury, older drivers are also overrepresented in certain types of crashes. In particular, they are more likely than drivers from younger age groups to be involved in crashes at intersections and crashes in which they were turning across oncoming traffic, disobeyed traffic signs or signals, or failed to give way to other traffic (Braitman, et al., 2007; Cooper, 1990; Mayhew, et al., 2006; Preusser, et al., 1998; Ryan, et al., 1998). This may be due to cognitive and sensory deficits that are part of the normal ageing process (Hakamies-Blomqvist, 1993; Larsen & Kines, 2002; McGwin Jr & Brown, 1999; Preusser, et al., 1998). However, older drivers are less likely to be involved in crashes resulting from deliberate unsafe actions, such as driving at excessive speeds or with an illegal blood alcohol concentration (Maycock, 1997; Mayhew, et al., 2006; OECD, 2001; Rakotonirainy, et al., 2012). They are also more likely than younger drivers to be found to be

responsible for the crashes in which they are involved (Langford, Koppel, et al., 2006; Mayhew, et al., 2006; Preusser, et al., 1998; Rakotonirainy, et al., 2012). However, this may result from their comparatively low involvement in crashes as the non-responsible party or from bias towards them when assessments of responsibility for crashes are made (Hakamies-Blomqvist, 2002; Hakamies-Blomqvist, 1993).

Although this review of previous research has indicated that older drivers are involved in fewer crashes than younger age groups and, overall, do not pose a risk on the road, it is possible that certain subgroups of older drivers do pose an unacceptable risk. This is because older drivers are not homogeneous in their driving abilities. Some are just as competent as middle-aged drivers, while others may be significantly impaired in their driving ability and may, therefore, have a higher than average crash risk (Baldock & McLean, 2005). The older drivers who may pose an unacceptable risk on the road are likely to be those who have impairments in their health and functional and cognitive abilities. As well as those abilities that were mentioned earlier in relation to their effect on the safe negotiation of certain driving situations (e.g. intersections), declines with age in many specific health, functional and cognitive factors have been shown to affect an individual's capacity to drive safely. The following section summarises these factors and the associated research.

Health, functional and cognitive factors related to driving ability and crash risk in older drivers.

Numerous studies have focused on determining the health, functional and cognitive factors that decline with age and are related to a decreased ability to drive and an increased crash risk. Firstly, as people age, they are more likely to have medical conditions that affect driving performance (Janke, 1994; Lindsay & Ryan, 2011; OECD, 2001; Smith et al., 2013; Vernon et al., 2002). In particular, the following conditions are associated with decreased driving ability and an increased crash risk:

- eye diseases, including cataracts (Charlton et al., 2010; Owsley et al., 2002; Owsley, Stalvey, Wells, & Sloane, 1999; Wood, 2002b; Wood & Carberry, 2006; Wood & Troutbeck, 1994), glaucoma (Haymes, LeBlanc, Nicolela, Chiasson, & Chauhan, 2007, 2008; McGwin Jr et al., 2005; Szlyk, Mahler, Seiple, Edward, & Wilensky, 2005; Wood, 2002b) and macular degeneration (Klein, 1991; Mangione, Gutierrez, Lowe, Orav, & Seddon, 1999; Szlyk et al., 1995),
- dementia (e.g. Alzheimer's disease and Huntington's disease) (Charlton, et al., 2010; Cooper, Tallman, Tuokko, & Beattie, 1993b; Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009; Duchek et al., 2003; Fitten et al., 1995; Friedland et al., 1988; Hunt, Morris, Edwards, & Wilson, 1993; Lindsay & Ryan, 2011; O'Neill et al., 1992; Ott et al., 2008; Rizzo, McGehee, Dawson, & Anderson, 2001; Tuokko, Tallman, Beattie, Cooper, & Weir, 1995),
- Cerebrovascular accidents (i.e. strokes and transient ischaemic attacks) (Lindsay & Ryan, 2011; Lundqvist, Gerdle, & Rönnberg, 2000; Lyman, McGwin Jr, & Sims, 2001; McGwin Jr, Sims, Pulley, & Roseman, 2000; Sims, McGwin Jr, Allman, Ball, & Owsley, 2000),
- Cardiovascular diseases (e.g. cardiac failure and heart disease) (Gallo, Rebok, & Lesikar, 1999; Lindsay & Ryan, 2011; McGwin Jr, et al., 2000),
- Diabetes (Koepsell et al., 1994; Lindsay & Ryan, 2011; Sagberg, 2006; Vernon, et al., 2002),
- Parkinson's disease (Heikkilä, Turkka, Korpelainen, Kallanranta, & Summala, 1998; Madeley, Hulley, Wildgust, & Mindham, 1990; Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006; Wood, Worringham, Kerr, Mallon, & Silburn, 2005; Zesiewicz et al., 2002),

- Seizure disorders (e.g. epilepsy) (Charlton, et al., 2010; Hansotia & Broste, 1991, 1993; Lindsay & Ryan, 2011; Taylor, Chadwick, & Johnson, 1996; Vernon, et al., 2002), and
- Psychiatric illnesses (e.g. schizophrenia, depression) (Lindsay & Ryan, 2011; Sims, et al., 2000; Vernon, et al., 2002).

The increase in medical conditions with age is also likely to lead to an increase in the use of medications that are used to treat these conditions, and these can also impair a person's driving performance. In particular, medications that affect the functioning of the central nervous system can impair driving. The following medications have been found to be associated with decreased driving ability and an increased crash risk in drivers of all ages, and in older drivers specifically:

- anti-depressants (Cooper, Meuleners, Duke, Jancey, & Hildebrand, 2011; Etminan, Hemmelgarn, Delaney, & Suissa, 2004; Leveille et al., 1994; Marottoli, 2002; Ray, Fought, & Decker, 1992),
- benzodiazepines (Cooper, et al., 2011; Engeland, Skurtveit, & Mørland, 2007; Hebert, Delaney, Hemmelgarn, Lévesque, & Suissa, 2007; Hemmelgarn, Suissa, Huang, Boivin, & Pinard, 1997; Madhusoodanan & Bogunovic, 2004; McGwin Jr, et al., 2000; Ray, Fought, et al., 1992; Walsh, Gier, Christopherson, & Verstraete, 2004),
- analgesics (Engeland, et al., 2007; Leveille, et al., 1994; Ray, Gurwitz, Decker, & Kennedy, 1992; Walsh, et al., 2004),
- hypnotics (Engeland, et al., 2007; Sims, et al., 2000),
- antipsychotics (Ray, Gurwitz, et al., 1992),
- antihypertensives (McGwin Jr, et al., 2000),
- non-steroidal anti-inflammatory drugs (Engeland, et al., 2007; Foley, Wallace, & Eberhard, 1995; McGwin Jr, et al., 2000),

- anticoagulants (McGwin Jr, et al., 2000), and
- hypoglycaemics (Hemmelgarn, Lévesque, & Suissa, 2006; Ray, Gurwitz, et al., 1992).

Furthermore, it is not uncommon for older adults to use several medications at once (Kaufman, Kelly, Rosenberg, Anderson, & Mitchell, 2002). This is referred to as ‘polypharmacy’ and it may lead to a greater overall effect on their ability to drive, especially if the different medications react with one another. Indeed, recent research from Sweden (Monárrez-Espino, Laflamme, Elling, & Möller, 2013) has found that the risk of a driver aged 50 to 80 years being involved in an injurious crash increases progressively with the number of medications that they are prescribed.

There are counter-arguments, however, to the notion that medication use by older drivers impairs their driving ability and increases their crash risk. For example, it may be the case that the crash risk of medicated older drivers would be worse if they were not using medication to treat their condition (Baldock, 2004; Marottoli, 2002). Moreover, it is also possible that the association between medications and an increased crash risk may simply be due to the effect of the underlying medical condition rather than the medication being used to treat it (Johansson, Bryding, Dahl, Holmgren, & Viitanen, 1997).

Other factors, which have been shown to be related to a decreased ability to drive and an increased crash risk, are age-related changes in various visual and physical functions. These include:

- visual acuity (i.e. the ability to see fine spatial detail) (Bowers et al., 2013; Decina & Staplin, 1993; Ivers, Boptom, & Cumming, 1999; Marottoli et al., 1998; Vernon, et al., 2002; Wood, 2002a),
- contrast sensitivity (i.e. the ability to distinguish an object that differs in luminance to the background) (Baldock, Mathias, McLean, & Berndt, 2006b; Bowers et al., 2013;

Decina & Staplin, 1993; Green, McGwin Jr, & Owsley, 2013; Ivers, et al., 1999; Wood, 2002a; Wood & Carberry, 2006),

- visual field (i.e. the extent of peripheral or side vision) (Decina & Staplin, 1993; Haymes, et al., 2007, 2008; Huisingsh, McGwin, Wood, & Owsley, 2014; McGwin Jr, et al., 2005; Rubin et al., 2007; Szlyk, et al., 2005), and
- flexibility of head and neck movement (Marottoli, et al., 1998).

Finally, age-related declines in certain cognitive abilities have also been shown to limit older peoples' ability to operate a motor vehicle safely. Abilities that have been shown to be related to driving ability and crash involvement include:

- attention (Anstey, Wood, Lord, & Walker, 2005; Baldock, et al., 2006b; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Brouwer, Waterink, Van Wolffelaar, & Rothengatter, 1991; Bunce, Young, Blane, & Khugputh, 2012; Cushman, 1996; Duchek, Hunt, Ball, Buckles, & Morris, 1998; Lesikar, Gallo, Rebok, & Keyl, 2002; Owsley et al., 1998; Richardson & Marottoli, 2003; Rizzo, et al., 2001),
- mental status (i.e. overall cognitive functioning and awareness) (Anstey, et al., 2005; Bowers et al., 2013; Fitten, et al., 1995; Johansson et al., 1996; Marottoli, Cooney, Wagner, Douchette, & Tinetti, 1994; Rizzo, et al., 2001),
- visuospatial, constructional, and motion processing abilities (Lesikar, et al., 2002; Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson, 1998; Marottoli, et al., 1994; Poulter & Wann, 2013; Rizzo, et al., 2001),
- memory (Anstey, et al., 2005; Foley, et al., 1995; Lundberg, et al., 1998; Richardson & Marottoli, 2003), and
- information processing speed (Anstey, et al., 2005; Baldock, et al., 2006b; Ball et al., 2006; Janke, 2001).

Summary issues relating to the safety of older drivers.

In summary, the main issues relating to the safety of older drivers are, firstly, that they are more likely to be seriously or fatally injured when they are involved in crashes than drivers in younger age groups (Baldock & McLean, 2005; Rakotonirainy, et al., 2012; Ryan, et al., 1998). Secondly, they are overrepresented in certain types of crashes (e.g. crashes at intersections) (Braitman, et al., 2007; Mayhew, et al., 2006; Preusser, et al., 1998; Ryan, et al., 1998). Thirdly, certain subgroups of older drivers are likely to have an elevated crash risk due to health, functional and cognitive impairments (Baldock, et al., 2006b; Baldock & McLean, 2005; Charlton, et al., 2010; McGwin Jr, et al., 2000; Wood, 2002a). As a result, the question facing researchers, road safety authorities and policymakers is how best to address these issues. There has been a considerable amount of research focusing on how to deal with the unique challenges that older drivers present in terms of safety on the road. However, there is also an increasing awareness that it is important to ensure that the mobility and well-being of older adults is maintained. The following sections provide a review of past research into these issues.

Issues Relating to the Safety, Driving Cessation and Mobility of Older Drivers

Mandatory fitness-to-drive assessments to manage the safety of older drivers.

The most common strategy that has been used to manage the safety of older drivers has been to develop re-licensing systems that differentiate between those older drivers who pose an excessive risk and should not continue to drive, and those who do not have an elevated risk of crashing. Relicensing practices for older drivers vary greatly between and within countries (Charlton, Koppel, Langford, & Irving, 2009; Langford et al., 2009; Langford & Koppel, 2006a), and these differences also exist between the states and territories of Australia (Charlton, et al., 2009; Langford, et al., 2009; Langford, Fitzharris, Newstead, & Koppel, 2004; Langford & Koppel, 2006a). Some jurisdictions, for example Victoria in

Australia, and Belgium, France and Germany in Europe, do not have compulsory regular assessments for licence renewal, which means that drivers are effectively licensed for life (Charlton, et al., 2009; Langford, et al., 2009; Langford & Koppel, 2006a). In contrast, other jurisdictions, such as New South Wales and Tasmania in Australia, and Finland, the Netherlands and the United Kingdom in Europe, have stringent requirements which usually involve mandatory fitness-to-drive assessments for all drivers over a certain age (Charlton, et al., 2009; Langford, et al., 2009; Langford & Koppel, 2006a). These may include vision, medical and on-road driving assessments. However, the age at which these assessments are required, as well as their regularity, also differ between jurisdictions (Charlton, et al., 2009; Langford, et al., 2009).

In South Australia, during the years in which the research detailed in this thesis was undertaken (2009 to 2012), drivers were required to undertake annual medical and vision tests from the age of 70, as well as on-road driving assessments when recommended by a medical practitioner, in order to have their licence renewed. At the end of 2013, however, the South Australian Government announced that mandatory age-based testing of fitness-to-drive would cease in South Australia (Charlton, et al., 2009; Langford, et al., 2009).

Problems with mandatory fitness-to-drive assessments.

The usefulness and nature of mandatory age-based fitness-to-drive assessments have been questioned for several reasons (Charlton, et al., 2009; Langford, Fitzharris, Koppel, & Newstead, 2004; Langford & Koppel, 2006a). Firstly, in regard to the usefulness of these practices, there has been insufficient evidence that they have a demonstrable road safety benefit (Grabowski, Campbell, & Morrisey, 2004; Hakamies-Blomqvist, 2002; Hakamies-Blomqvist, Johansson, & Lundberg, 1996; Lange & McKnight, 1996; Langford, Bohensky, Koppel, & Newstead, 2008; Langford, Fitzharris, Koppel, et al., 2004; Langford, Fitzharris, Newstead, et al., 2004; Langford & Koppel, 2006a; Rock, 1998; Siren & Meng, 2012; Stav,

2014; Torpey, 1986). This has been found by various studies that compare the crash rates of older drivers in jurisdictions that impose mandatory testing with those that do not. For example, research in Europe by Hakamies-Blomqvist et al. (1996) examined the safety effects of the different licensing practices of Finland and Sweden. Regular medical assessments starting at age 70 are required for licence renewal in Finland, while Sweden has no age-based assessments at all. This study found that the crash rates per head of population of older drivers in Finland were not lower than those in Sweden, which suggested that there was no safety benefit from the practice of age-based medical screening of older drivers. Moreover, it was found that Finland had a higher fatality rate for older pedestrians. It was suggested that this may have resulted from an increased number of older drivers in Finland giving up their licenses voluntarily, rather than undertaking the relicensing assessments, and relying on walking as their main mode of transportation. These older ex-drivers were then vulnerable as pedestrians because of their physical fragility. Therefore, it was concluded that Finland's relicensing practices may actually have had an adverse safety implication for older road users (Hakamies-Blomqvist et al., 1996).

Research by Grabowski et al. (2004) examined the effectiveness of the different licensing practices that are used in various states in the USA in terms of reducing older driver fatality rates. The four practices that were investigated were: laws mandating in-person renewal, laws mandating vision tests, laws mandating on-road tests, and length of renewal period. The only practice that was significantly associated with a lowered fatality rate was in-person licence renewal, and only in the case of drivers who were aged 85 years or older. Thus, this suggests that more stringent licence renewal practices, such as vision and on-road tests, as well as more frequent assessments, may not result in the desired road safety benefits.

In Australia, research by Torpey (1986) compared the crash rates of drivers aged 70 and over in the state of Victoria to those in the other Australian states. Victoria, which was the only jurisdiction not requiring age-based assessments, had crash rates that were similar to the

other states. This finding has also been confirmed more recently in studies by Langford, Fitzharris, Koppel, et al. (2004), Langford, Fitzharris, Newstead, et al. (2004) and Langford, Bohensky, et al. (2008), which again showed that the crash rates of older drivers (aged 80 years and older) in Victoria were comparable to those in other Australian states. In addition, they found that older driver casualty crash rates on a per licensed driver and per time spent driving basis were actually statistically higher in other states compared to Victoria. Consequently, these studies all demonstrate that implementing stringent age-based assessments of fitness-to-drive does not lead to a reduction in the crash involvement of older drivers.

In addition to the debate about mandatory age-based testing, there has been concern regarding the nature of the assessments. Firstly, assessing every person over a certain age is not cost- or time-effective (OECD, 2001). Instead, assessments need to target those who are more likely to pose a risk. Secondly, this practice is potentially age-discriminatory (Charlton, et al., 2009). Thirdly, chronological age, itself, does not adequately predict the decline in driving ability or the increase in crash risk (Baldock, 2004; Ball & Owsley, 2003; Ball, et al., 1993; Mathias & Lucas, 2009; Maycock, 1997; Sommer, Falkmer, Bekiaris, & Panou, 2004). As mentioned, older drivers are not homogeneous in their driving abilities. Some are just as competent as middle-aged drivers, while others may be significantly impaired in their driving ability and may, therefore, have a higher crash risk. As a result, age alone is not an indicator of a person's likely capacity to drive safely.

A person's capacity to drive safely is likely to be more adequately predicted by their health, functional and cognitive abilities. This is because particular subgroups of older drivers may be at greater risk of crashing due to significant impairments in these abilities. Consequently, instead of requiring every person over a certain age to undertake fitness-to-drive assessments, it may be more effective if assessments are performed when concerns are raised by medical practitioners about an individual's functioning and driving capacity. Thus,

drivers of all ages could be screened, using measures of health, functional and cognitive abilities, to identify those with a potentially high crash risk who would then undertake more comprehensive and expensive fitness-to-drive assessments, such as on-road tests (Langford, Braithwaite, et al., 2008; McKenna, Jefferies, Dobson, & Frude, 2004; Niewoehner et al., 2012).

As noted earlier in the discussion on the safety of older drivers, numerous health, functional and cognitive declines are related to decreased driving performance in drivers of all ages. However, the extent of decline and the degree to which it affects driving performance varies greatly between individuals (Daigneault, Joly, & Frigon, 2002a; Hakamies-Blomqvist, 1998; Janke, 1994; Klavora & Heslegrave, 2002; Langford & Koppel, 2006a; Marottoli, 2002; Wallace & Retchin, 1992). Furthermore, there are many different measures of these factors (Mathias & Lucas, 2009) and it is unclear what measures best predict driving ability (Bedard, Weaver, Darzins, & Porter, 2008; Molnar, Patel, Marshall, Man-Son-Hing, & Wilson, 2006). Mathias and Lucas (2009) undertook a meta-analysis examining the cognitive predictors of driving performance in older drivers in order to identify cognitive tests that could be used to make decisions about an individual's driving competence. They reported considerable variability in the extent to which the available measures of cognitive ability are able to discriminate between safe and unsafe older drivers, with some being better than others. However, there is currently no consensus in terms of which measure, or combination of measures, provides the best option for screening potentially unsafe older drivers (Carr & Ott, 2010; Mathias & Lucas, 2009). Moreover, research in Western Australia by Langford et al. (2009), which examined the usefulness of a range of leading screening tests, found no evidence that these tests were able to distinguish between unsafe (recently involved in at-fault casualty crashes) and safe (not involved in crashes) drivers aged 75 years and older. As a result, Langford et al. (2009) doubted whether these tests would be useful to licensing authorities.

Mobility importance and the problems of driving cessation.

Another problem with mandatory age-based fitness-to-drive assessments as an approach to the management of the safety of older drivers is that they can lead to driving cessation for individuals who would otherwise be safe to continue driving. This can occur through an inaccurate assessment, whereby an older person is incorrectly deemed to be no longer safe to drive (Langford, 2008). It can also occur because the process of undertaking the test can influence their decision to reduce or cease driving (Kulikov, 2011). In other words, these assessments can be daunting for the older person, so much so that they may give up their licenses, and therefore their mobility, prematurely to avoid the test (Charlton, et al., 2009; Charlton, 2002; Hakamies-Blomqvist, et al., 1996; Oxley, Charlton, & Fildes, 2003). In this way, age-based testing may actually deter safer, more conscientious drivers from having their licence renewed (Eberhard, 1996; Lange & McKnight, 1996).

The ability and freedom to drive is extremely important to older adults. Research has shown that the mobility that driving provides is important for their independence (Adler, et al., 1999; Burns, 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Lister, 1999; Peel, Westmoreland, & Steinberg, 2002; Snellgrove, 2005; Whitehead, Howie, & Lovell, 2006; Yassuda, Wilson, & Mering, 1997), convenience (Adler, et al., 1999; Lister, 1999; Persson, 1993; Snellgrove, 2005; Whitehead, et al., 2006), self-worth (Adler, et al., 1999; Eisenhandler, 1990; Freund & Szinovacz, 2002; Whitehead, et al., 2006), social network (Mezuk & Rebok, 2008; Whitehead, et al., 2006), and for an active lifestyle (Adler, et al., 1999; Fonda, et al., 2001; Hakamies-Blomqvist, 2002; Harris, 2002; Klavora & Heslegrave, 2002; Lister, 1999; Marottoli, et al., 2000; Peel, et al., 2002; Whitehead, et al., 2006). Moreover, when an older person ceases driving, their mobility can be greatly reduced. For example, research by Rosenbloom (2001) examined the travel behaviour of a group of older drivers who had ceased driving within one year after an initial interview. It was found that, after driving cessation, the amount of travel that they undertook daily (both in terms of the

number of trips and the distance they travelled) had reduced by almost two-thirds. Similarly, other studies by Marottoli et al. (2000) and Peel et al. (2002) found that driving cessation results in older people engaging in fewer activities outside of their home. In research by Bonnel (1999), older women reported that they gave up activities such as social outings, church attendance, volunteer work, and visiting family when they stopped driving. Consistent with this, Davey (2007) indicated that ex-drivers are more likely to give up discretionary trips, which contribute significantly to their quality of life (e.g. visiting friends), than non-discretionary trips (e.g. shopping).

This loss of mobility through driving cessation can have considerable effects on the health and well-being of older people. In particular, it has been shown to lead to depression (Fonda, et al., 2001; Marottoli, Mendes de Leon, et al., 1997; Ragland, Satariano, & MacLeod, 2005; Snellgrove, 2005; Windsor, Anstey, Butterworth, Luszcz, & Andrews, 2007). For example, longitudinal research in the USA by Marottoli et al. (1997) found that older individuals who had stopped driving demonstrated substantial increases in depressive symptoms. This has also been shown to be the case in more recent longitudinal studies in the USA by Fonda et al. (2001) and Ragland (2005), with the Fonda et al. study reporting that older individuals who had ceased driving were at 1.4 times the risk of increased depressive symptoms, compared to those who still drove. Similarly, in Australia, longitudinal research by Windsor et al. (2007) found an increase in depressive symptoms in older adults who had stopped driving. Furthermore, driving cessation has also been shown to lead to an increased risk of mortality in research by Edwards, Perkins, Ross, and Reynolds (2009). This study examined a cohort of older adults (aged 63 - 97 years) and, after controlling for demographics and health, functional, cognitive and psychological factors, found that non-drivers were four to six times more likely to die than continuing drivers during an ensuing three year period.

Furthermore, if older drivers cease driving, they may change to riskier modes of travel (Hakamies-Blomqvist, 2002; Hakamies-Blomqvist, et al., 1996; Siren & Meng, 2012).

Indeed, it has been shown that older adults are at a greater risk of being killed as pedestrians than as car drivers on a per trip basis (Langford & Koppel, 2006a; OECD, 2001). In addition, research by Martin, Hand, Trace, and O'Neill (2010) demonstrated that older pedestrians (aged 65 and older) are more than twice as likely than younger pedestrians (aged 16 to 64) to be killed when hit by a vehicle. This is likely to be because older drivers who cease driving because of declining health or functional and cognitive abilities may also be too fragile to be pedestrians. Thus, their health and fragility would result in their being more likely to be severely or fatally injured if they are struck by a car or fall down as a pedestrian, and may also result in greater difficulty negotiating road environments as a pedestrian (Dommes & Cavallo, 2011; OECD, 2001; Oxley, 2009; Oxley, Ihnsen, Fildes, Charlton, & Day, 2005). Indeed, research involving persons aged 72 years or older in the USA by Langlois, Keyl, Guralnik, Foley, Marottoli, and Wallace (1997) found that 11% of participants reported difficulty crossing the street and less than one per cent of participants had a walking speed that would be sufficient to cross the street in the time typically allocated at signalised intersections. Consistent with this, more recent studies from Ireland (Romero-Ortuno, Cogan, Cunningham, & Kenny, 2010), the UK (Asher, Aresu, Falaschetti, & Mindell, 2012) and South Africa (Amosun, Burgess, Groeneveldt, & Hodgson, 2007) have shown that standard crossing times at pedestrian lights are insufficient for older people.

Consequently, despite potential issues relating to the safety of older drivers on the road, the focus of recent research has been on encouraging older adults to maintain their driving mobility for as long as it remains reasonable to do so (Anderson, Anstey, & Wood, 2009; Dickerson et al., 2007; Marottoli & Coughlin, 2011; Oxley & Whelan, 2008; Windsor & Anstey, 2006). Research (Ross, Schmidt, & Ball, 2013) has also sought to identify ways to assist older adults to continue driving and maintain their mobility for as long as possible, through cognitive training, education, and exercise.

Transition from driver to non-driver.

Although there are numerous reasons for older adults to continue driving, cessation is often necessary. Indeed, research by Foley, Heimovitz, Guralnik, and Brock (2002) estimated that the total life expectancy of drivers in the USA aged 70 to 74 years exceeds their driving life expectancy by about seven years for men and ten years for women. Research by Persson (1993), based on interviews with older people about driving cessation, indicated that it occurs either as a gradual change in driving behaviour (e.g. a gradual reduction in the amount of driving to compensate for declining health, functional and cognitive factors) or a sudden change (e.g. in response to a stroke or involvement in a crash). Moreover, the process is difficult for older individuals and their families (Connell, Harmon, Janevic, & Kostyniuk, 2013; Harris, 2002; Stutts, Wilkins, Reinfurt, Rodgman, & Van Heusen-Causey, 2001; Whitehead, et al., 2006). In qualitative research by Whitehead et al. (2006), five older ex-drivers who were interviewed reported that driver licence cancellation was a deeply traumatic and shocking experience, and that when it occurred they felt like their life was over. It is not surprising, therefore, that it is often met with reluctance by older individuals (Adler & Rottunda, 2006; Persson, 1993), particularly if there are no other ways of remaining mobile. Indeed, the availability and acceptability of alternative transport options, such as public transport, may be unsatisfactory (Harris, 2002; Lister, 1999; Peel, et al., 2002). Additionally, family members or friends may not be available to provide transport (Johnson, 1995), or the older adults may feel that they do not want to impose or depend on them (Adler & Rottunda, 2006; Bauer, Rottunda, & Adler, 2003; Davey, 2007; Peel, et al., 2002). Therefore, life without a car and the resulting loss of independence can be difficult to adjust to.

Studies have also shown that older individuals do not plan for how they will meet their mobility needs if the time comes when they can no longer drive (Harris, 2002; Kostyniuk & Shope, 2003; Peel, et al., 2002; Rudman, Friedland, Chipman, & Sciortino, 2006; Silverstein, 2008; Stutts, et al., 2001). For example, out of 67 former drivers that were interviewed in

research by Kostyniuk and Shope (2003), none had made formal preparations in advance for driving cessation, making the transition from driver to non-driver even more difficult. Planning ahead may help to smooth the transition, both emotionally and practically, and assist with maintaining a degree of mobility. Consistent with this, Bauer (2003) interviewed former drivers and found that those who had planned ahead for driving cessation adapted more easily to life without a licence. It has been suggested that interventions could assist older adults to make preparations for driving cessation and that family, friends and professionals (e.g. general practitioners, social workers, occupational therapists) could be involved in these interventions (Adler & Rottunda, 2006; Betz, Jones, Petroff, & Schwartz, 2013; Kostyniuk & Shope, 2003; Liddle, McKenna, & Bartlett, 2007; Mullen & Bédard, 2009; Windsor & Anstey, 2006). Preparations could include: moving closer to family and/or friends, moving closer to a public transport route, becoming accustomed to using public transport, increasing awareness of the alternative transport options that are available, budgeting travel expenses, and deciding on an appropriate time to stop driving (Adler & Rottunda, 2006; Mullen & Bédard, 2009; Windsor & Anstey, 2006).

Self-regulation.

One potential way for older drivers to both manage their own safety on the road and maintain their mobility is to self-regulate their driving (Berry, 2011; D'Ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Okonkwo, Crowe, Wadley, & Ball, 2008; Stalvey & Owsley, 2000). Self-regulation refers to voluntarily adjusting one's driving in order to prevent crash involvement (Baldock, Mathias, McLean, & Berndt, 2006a; Baldock, et al., 2006b; D'Ambrosio, et al., 2008). This can be undertaken through a reduction in the overall amount of driving or by avoiding driving situations that are perceived to be difficult (e.g. driving in peak hour traffic) (Baldock, et al., 2006a; Charlton, Oxley, Fildes, Oxley, & Newstead, 2003; Molnar & Eby, 2008; Molnar, Eby, Charlton, et al., 2013). This offers older drivers a way of

continuing to drive while, at the same time, reducing their exposure to driving conditions that they find difficult, thereby increasing their safety (Baldock, et al., 2006a; Baldock, et al., 2006b; Stalvey & Owsley, 2000). It is also important for people as they age because it can be undertaken in accordance with declining driving, cognitive and functional abilities, as well as deteriorating health, in order to improve their safety. Self-regulation may ultimately lead to the eventual decision to stop driving if an individual believes that they are no longer safe on the road, but at least this cessation would occur through a gradual reduction of driving and with the individual maintaining a sense of control.

The driving situations that older drivers commonly avoid.

Past research into driving self-regulation has examined the driving situations that older drivers commonly avoid. These include:

- driving at night (Baldock, et al., 2006a; Baldock, Thompson, & Mathias, 2008; Ball et al., 1998; Charlton, et al., 2003; Charlton et al., 2006; Cooper, 1990; Daigneault, et al., 2002a; Eberhard, 1996; Holland & Rabbitt, 1994; Lundqvist, et al., 2000; Molnar & Eby, 2008; Molnar, Eby, Langford, et al., 2013; Okonkwo, et al., 2008; Raitanen, Tormakangas, Mollenkopf, & Marcellini, 2003; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998),
- inclement weather (e.g. in rain or snow) (Baldock, et al., 2006a; Baldock, Thompson, et al., 2008; Charlton, et al., 2006; Lundqvist, et al., 2000; Molnar & Eby, 2008; Okonkwo, et al., 2008; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998),
- busy traffic (i.e. on busy roads or in peak hour traffic) (Ball, et al., 1998; Charlton, et al., 2006; Cooper, 1990; Holland & Rabbitt, 1994; Okonkwo, et al., 2008; Rimmo & Hakamies-Blomqvist, 2002; Schlag, 1993; Stutts, 1998),

- high speed roads (e.g. freeways) (Baldock, et al., 2006a; Ball, et al., 1998; Choi, Adams, & Kahana, 2013; Eberhard, 1996; Molnar, Eby, Langford, et al., 2013),
- unfamiliar areas or roads (Burns, 1999; Cotrell & Wild, 1999; Eberhard, 1996; Molnar & Eby, 2008; Molnar, Eby, Langford, et al., 2013; Okonkwo, et al., 2008; Raitanen, et al., 2003), and
- unprotected turns across traffic or at complex intersections (Holland & Rabbitt, 1992, 1994; Okonkwo, et al., 2008).

Factors that are related to increased self-regulation by older drivers.

Research has also investigated some of the variables that are associated with increased self-regulation by older drivers (i.e. either reduction in the overall amount of driving or avoidance of difficult driving situations). In particular, the following factors have been identified:

- increasing age (Burns, 1999; Charlton, et al., 2006; Forrest, Bunker, Songer, Coben, & Cauley, 1997; Freund & Szinovacz, 2002; Gallo, et al., 1999; Holland & Rabbitt, 1994; Okonkwo, et al., 2008; Raitanen, et al., 2003; Rimmo & Hakamies-Blomqvist, 2002; Ross et al., 2009),
- female gender (Burns, 1999; Charlton, et al., 2003; Charlton, et al., 2006; D'Ambrosio, et al., 2008; Gallo, et al., 1999; Kostyniuk & Molnar, 2008; Molnar & Eby, 2008; Okonkwo, et al., 2008; Raitanen, et al., 2003; Rimmo & Hakamies-Blomqvist, 2002; Siren & Meng, 2013),
- retirement (Braitman & Williams, 2011; Charlton, et al., 2003; Eberhard, 1996),
- previous crashes (Ball, et al., 1998; Charlton, et al., 2003; Charlton, et al., 2006),
- driving confidence (Baldock, et al., 2006a; Charlton, et al., 2003; Charlton, et al., 2006),

- driving ability (in terms of on-road driving test scores) (Baldock, et al., 2006a; Molnar & Eby, 2008),
- difficulty in specific driving situations (e.g. driving at night) (Cooper, 1990; Owsley, et al., 1999),
- deteriorating health (Baldock, et al., 2006b; Burns, 1999; Choi, et al., 2013; Forrest, et al., 1997; Freund & Szinovacz, 2002; Okonkwo, et al., 2008; Raitanen, et al., 2003; Rimmo & Hakamies-Blomqvist, 2002),
- use of medications (Baldock, et al., 2006b),
- decreased visual attention (Baldock, et al., 2006b; Ball, et al., 1998; Okonkwo, et al., 2008; Vance et al., 2006),
- visual impairments (Adler, Bauer, Rottunda, & Kuskowski, 2005; Baldock, et al., 2006b; Ball, et al., 1998; Charlton, et al., 2006; Freeman, Munoz, Turano, & West, 2005; Freund & Szinovacz, 2002; Owsley, et al., 1999; Ragland, Satariano, & MacLeod, 2004; Satariano, MacLeod, Cohn, & Ragland, 2004; Stutts, 1998), and
- cognitive impairments (e.g. dementia) (Cotrell & Wild, 1999; Festa, Ott, Manning, Davis, & Heindel, 2013; Freund & Szinovacz, 2002; Meng & Siren, 2012; Stutts, 1998).

Extent of self-regulation by older drivers.

Older drivers may not self-regulate to an appropriate level of their own accord.

Research has found that, in general, older drivers travel fewer kilometres per year than younger drivers (Baldock & McLean, 2005; Collia, et al., 2003; Eberhard, 1996; Li, et al., 2003; Lyman, et al., 2002; Maycock, 1997; Ryan, et al., 1998), but other research has found only low levels of avoidance of difficult driving situations by older drivers (Baldock, et al., 2006a; Baldock, et al., 2006b; Baldock, Thompson, et al., 2008; Stalvey & Owsley, 2000; Sullivan, Smith, Horswill, & Lurie-Beck, 2011). For example, Stalvey and Owsley (2000)

interviewed drivers aged over 64 years who had been involved in a crash in the previous year and who had impaired visual abilities. They found that 75% of the participants reported “never” or “rarely” avoiding difficult driving situations. However, 91% believed that impaired vision affected driving ability and 89% thought that such impairments would be noticeable. Despite this, 70% rated their vision as “excellent” or “good” and 82% reported no difficulty with driving in challenging situations. This suggests that the participants were not aware of their visual impairments and, consequently, were not self-regulating their driving to compensate for them.

Other studies have found that older drivers may not be prompted to self-regulate their driving by declining health, cognition, and functional abilities that affect driving ability and increase crash risk (Baldock, et al., 2006b; Baldock, Thompson, et al., 2008; Holland & Rabbitt, 1992; Okonkwo, et al., 2008; Wong, Smith, & Sullivan, 2012). Research in South Australia by Baldock et al. (2006b) examined these variables in drivers aged 65 years and older, and the relationship between these factors and both driving ability (i.e. scores on an on-road driving test) and self-regulation (i.e. self-reported avoidance of difficult driving situations). It was found that measures of contrast sensitivity, speed of information processing and visuospatial memory were related to driving ability, but not self-regulation.

Furthermore, a longitudinal assessment of the self-regulatory driving practices of the same cohort of older drivers was undertaken four to five years later by Baldock, Thompson, et al. (2008). It was shown that, in the interim, significant cognitive and functional decline occurred - in terms of mental status, visual acuity, contrast sensitivity and visual attention - but there was no corresponding increase in the degree to which they avoided difficult driving situations to compensate. Contradictory results have been found, however, in longitudinal research from the USA by Ross et al. (2009). They found that older drivers who were at-risk of crashes because of reduced functional abilities (in terms of psychomotor abilities, visuospatial abilities and speed of information processing) reported more avoidance of

difficult driving situations than lower-risk participants at baseline, and also increased their self-regulation over the five year study period at a faster rate than lower-risk participants.

One explanation for the finding that older drivers may not appropriately self-regulate to compensate for health, cognitive and functional impairments is that they may not be aware of these impairments or the effect that they have on their driving ability (Adler, et al., 1999; Cotrell & Wild, 1999; Cushman, 1996; Okonkwo, et al., 2008; Stalvey & Owsley, 2000).

Consistent with this, Stavey and Owsley (2000) reported that their participants were not appropriately self-regulating because they were not aware of their visual impairments. A lack of awareness into one's abilities may, in turn, be the result of cognitive impairments, such as dementia. Indeed, research has suggested that, although cognitive problems affect driving ability, some older drivers with these problems may not adequately self-regulate because they lack insight into their abilities (Adler, et al., 1999; Ball, et al., 1998; Cotrell & Wild, 1999). For example, Adler et al. examined the driving habits of older adults with dementia and found that 51% adjusted their driving behaviour over the previous year, but 36% still drove daily and frequently at night, on freeways, in heavy traffic, and alone.

However, it may also be the case that older drivers do not self-regulate appropriately, simply because they do not want to restrict their mobility and, therefore, their independence and activity level. Consistent with this, older drivers in research by Baldock et al. (2006a) reported that the main barrier to changing when and where they drive was the maintenance of their lifestyle.

Educational interventions to encourage self-regulation.

If older drivers are made aware of any decline in their abilities, they may make adjustments to their driving (Holland & Rabbitt, 1992), raising the possibility that older drivers could be taught to self-regulate to a more appropriate level. This could be particularly useful for those who have health, functional or cognitive declines or those who, for any other

reason, are at risk on the road (Charlton, et al., 2003; Stalvey & Owsley, 2000). Indeed, an educational intervention to teach self-regulation to older drivers who had a high crash risk, due to vision impairment, previous recent crash involvement, and high driving exposure, has been trialled by Owsley, Stalvey, and Phillips (2003) with successful results. The aim of the intervention was to increase self-awareness about visual impairments, and their effect on driving safety, and to promote self-regulation. At six months post-intervention, the older drivers were more likely than a control group (who were not given the intervention) to acknowledge their visual impairments and the effect that they had on driving. They were also more likely to practice self-regulation, in terms of avoiding difficult driving situations and reducing their driving exposure. However, subsequent research (Owsley, McGwin Jr, Phillips, McNeal, & Stalvey, 2004), which examined the crash involvement of the intervention and control groups over a two year period, found that they did not differ. Thus, the practice of self-regulation may not have a road safety benefit in terms of reduced crash involvement.

The road safety benefits of practicing self-regulation.

Other research has also failed to demonstrate that self-regulation leads to lower crash involvement for those who practice it (Ball, et al., 1998; Ross, et al., 2009). If self-regulation is to be promoted, it must be shown to benefit the safety of those who practice it, in terms of reducing their crash risk. Multiple factors influence crash involvement, however, and crashes are not always caused through a fault on the part of the individual, but are often caused by external events that the individual cannot control or avoid, such as other drivers or environmental circumstances (Owsley, et al., 2004). As Owsley et al. (2004) suggested, “it might be overly simplistic to expect that educational programs by themselves, however thorough and individualized, would affect crash rate” (p.227). Moreover, crashes are relatively rare events. Consequently, an individual with impaired driving ability may not be involved in a crash over a given time period. Crash involvement may, therefore, be an

unreliable outcome measure for research, making it difficult to definitively demonstrate that self-regulation reduces crash involvement.

As discussed, research has indicated that older drivers have low crash rates at night, on weekdays, during peak hour, and in inclement weather (Catchpole, et al., 2005; Cooper, 1990; McGwin Jr & Brown, 1999; OECD, 2001; Stutts & Martell, 1992; Zhang, et al., 1998), possibly reflecting flexibility in when they do their driving. As a result, they are able to choose not to drive in these difficult conditions (Cooper, 1990; Maycock, 1997). Thus, self-regulation may be successful at reducing crashes in certain situations for older drivers at the population level, even though it has proven difficult to demonstrate statistically at the individual level.

In addition, the findings of recent research by Freund and Petrakos (2008) have been promising in relation to the safety benefits of avoiding difficult driving situations. This study assessed the performance on a driving simulator of a sample of cognitively impaired older drivers. Based on their performance (in terms of the number and type of driving errors) they were grouped as safe, conditionally safe (with restrictions), and unsafe. The conditionally safe group were instructed to make restrictions to their driving (e.g. no highway driving), based on specific errors that were made on the driving simulator. The safe and conditionally safe groups were then compared in terms of their crash involvement and traffic violations over the ensuing one and half year period. They found that only one person, who was in the safe group, committed a traffic violation. The authors used this as evidence that the driving restrictions had kept the crashes and violations of the conditionally safe group to the same level as the safe group. However, both the sample size and the period over which crashes and violations were assessed were small. As mentioned, crashes are rare events; therefore, the absence of crashes and violations for the conditionally safe group may have been unrelated to the driving restrictions. Thus, at present, the road safety benefit for older drivers of avoiding difficult driving situations, and of self-regulation in general, remains unclear.

Summary: issues of safety management, driving cessation and mobility importance for older drivers.

In summary, the most common strategy that has been used to manage the safety of older drivers has been to develop re-licensing systems (e.g. mandatory fitness-to-drive assessments for all drivers over a certain age) that differentiate those older drivers who are safe to continue driving from those who are not. However, this practice has been questioned (Charlton, et al., 2009; Langford, Fitzharris, Koppel, et al., 2004; Langford & Koppel, 2006a), particularly because chronological age by itself is not an adequate predictor of decline in driving ability or increased crash risk (Marottoli et al., 1998; Vernon, et al., 2002; Wood, 2002a). Therefore, attempts have been made to address this by examining the health, functional and cognitive factors that are related to decreased driving ability and increased crash risk in older drivers (Baldock, et al., 2006b; Charlton, et al., 2010; McGwin Jr, et al., 2000; Wood, 2002a), in the hope that inclusion of these measures in fitness-to-drive assessments will more successfully identify unsafe individuals (Langford, Braitman, et al., 2008; McKenna, et al., 2004; Niewoehner et al., 2012). However, despite considerable research in this area, there is currently no consensus regarding the measures that best predict ability to drive and identify unsafe drivers (Bedard, et al., 2008; Carr & Ott, 2010; Mathias & Lucas, 2009; Molnar, et al., 2006). Furthermore, in addition to a lack of consensus on what to measure when relicensing older drivers, the practice of mandatory age-based assessments of fitness-to-drive has not been found to lead to a reduction in the crash involvement of older drivers (Grabowski, et al., 2004; Hakamies-Blomqvist, et al., 1996; Langford, Bohensky, et al., 2008; Langford, Fitzharris, Koppel, et al., 2004; Langford, Fitzharris, Newstead, et al., 2004; Torpey, 1986).

Another problem with mandatory age-based fitness-to-drive assessments is that they can lead to some older drivers prematurely surrendering their licences and, therefore, losing

the mobility that driving provides (Charlton, et al., 2009; Kulikov, 2011; Langford, 2008; Oxley, et al., 2003). Mobility is important for the independence, convenience, self-worth, social networks and active lifestyles of older adults (Adler, et al., 1999; Lister, 1999; Whitehead, et al., 2006). Moreover, the loss of mobility through driving cessation can have adverse affects on the health and well-being of older adults (Edwards, et al., 2009; Fonda, et al., 2001; Marottoli, Mendes de Leon, et al., 1997) and this has resulted in recent efforts to encourage them to continue driving for as long as it remains safe to do so (Anderson, et al., 2009; Dickerson, et al., 2007; Marottoli & Coughlin, 2011; Oxley & Whelan, 2008).

Ultimately, however, for many older drivers there will come a time when they must stop driving (Foley, et al., 2002). This can be a difficult and traumatic process for many older adults (Connell, et al., 2013; Harris, 2002; Whitehead, et al., 2006), and one that they often do not prepare for (Harris, 2002; Kostyniuk & Shope, 2003; Silverstein, 2008). Therefore, interventions that help prepare older adults may help them to transition to being a non-driver (Adler & Rottunda, 2006; Mullen & Bédard, 2009; Windsor & Anstey, 2006).

One potential way for older drivers to both manage their own safety on the road and maintain their mobility is to self-regulate their driving (Berry, 2011; D'Ambrosio, et al., 2008). This involves individuals voluntarily reducing the overall amount that they drive and/or the amount that they drive in difficult conditions (e.g. peak hour traffic) in order to reduce their risk of crash involvement (Baldock, et al., 2006a; Baldock, et al., 2006b; Charlton, et al., 2003). It offers a way of continuing to drive, while also reducing exposure to difficult driving conditions, thereby increasing safety (Baldock, et al., 2006a; Baldock, et al., 2006b; Stalvey & Owsley, 2000). However, some older drivers may not adjust their driving adequately to compensate for their declining health, and changes in the cognitive and functional abilities that affect their ability to drive (Baldock, et al., 2006b; Baldock, Thompson, et al., 2008; Stalvey & Owsley, 2000). Additionally, the road safety benefits of

self-regulation for drivers who do practice it, currently remain unclear (Ball, et al., 1998; Owsley, et al., 2004; Ross, et al., 2009).

Overall, this review of the literature has demonstrated that there are a number of important issues relating to the safety and mobility of older drivers. However, these issues of safety and mobility may be even more important for older drivers who live in rural and remote areas. This is the focus of the second chapter.

Chapter 2: The Safety and Mobility of Older Rural Drivers

Older drivers who live in rural or remote areas are the focus of the current thesis. This is because the circumstances of living in rural and remote areas, with longer distances to travel, increased importance of driving, limited alternative transportation and roads with high speed limits, may both increase their risk on the road and further restrict their mobility compared to older drivers from urban areas. In particular, this thesis examines the safety and mobility of older drivers who live in rural or remote areas of South Australia, compared to their urban counterparts. To date, there has only been limited past research, both internationally and in Australia, specifically investigating the safety and mobility of older rural drivers. This chapter provides a review of the existing literature in this area, beginning with an evaluation of research into their safety, in terms of the overall crash involvement of rural drivers compared to that of their urban counterparts, as well as their risk of serious or fatal injury, in order to determine whether they may be at greater risk on the road than older urban drivers. This is followed by an examination of research into the driving mobility of older rural drivers, in order to determine whether their mobility may be restricted by the longer distances that need to be travelled in rural areas to reach destinations. The practice of self-regulation by older rural drivers is then examined, in order to determine whether their ability to self-regulate is also restricted by living in rural areas. This chapter also identifies the main areas where further research is needed and finishes by providing an overview of the general and specific aims of the research that is outlined in the remaining chapters in this thesis.

The Safety of Older Rural Drivers

Crash involvement.

Research has demonstrated that rural drivers, irrespective of age, are involved in fewer crashes than urban drivers. For example, Zwerling et al. (2005) demonstrated that rural drivers in the USA have a lower total number of crashes than urban drivers, as well as a lower crash rate per million miles driven. This also appears to be the case for older rural drivers (Finison & Dubrow, 2002; Foley, et al., 1995; Zwerling, et al., 2005). When Foley et al. (1995) examined the 5-year crash involvement of a cohort of older rural drivers (aged 68 years and older), they found that the estimated annual crash rate for the sample of older rural drivers (28 crashes per 1,000 driving years) was approximately 20% lower than the national rate for all drivers aged 65 years and over (36 crashes per 1,000 driving years).

This difference in the crash rates of rural and urban areas is likely to be related to the nature of the respective driving environments. Urban areas are characterised by a higher traffic volume and more potential conflict points (e.g. intersections), while rural areas have lower traffic volumes and fewer conflict points on highways and freeways. In Chapter 1 the ‘low mileage bias’ for crash involvement was described, whereby drivers who travel smaller distances, on average, are involved in more crashes on a distance driven basis than those who travel longer distances (Hakamies-Blomqvist, 2002; Hakamies-Blomqvist, et al., 2002; Janke, 1991; Langford, et al., 2013; Langford, Methorst, et al., 2006; Maycock, 1997). The explanation for this that has been suggested by Janke (2001) is that high mileage drivers may be more likely to accumulate much of their mileage on freeways, where lanes travelling in opposite directions are divided, access from other roads is restricted, and crashes are rare. In comparison, low mileage drivers may be more likely to drive on local roads with more potential crash points and more congestion. Rural drivers, who tend to travel longer annual distances than urban drivers (Mattson, 2013), are likely to spend more time driving in road

environments that are characterised by few conflict points and limited congestion and, therefore, have a low crash risk per unit of distance.

However, recent research from Canada, by Hanson and Hildebrand (2011b), has suggested that the phenomenon of low-mileage bias may not exist for *older* rural drivers. This study used both Global Positioning Systems (GPS) and self-report methods to measure the driving of a sample of rural drivers aged 54 to 92 years. It was found that the proportion of travel on urban streets by the older rural participants increased with self-reported mileage and decreased with age. The authors also referred to previous research by Hildebrand, Myrick and Creed (2000 as cited in Hanson & Hildebrand (2011b)) which compared rural and urban drivers of various age groups in terms of their collision rates per million kilometres driven. The study by Hildebrand et al. (2000) found that rural drivers had lower collision rates in all age groups, including the 66 to 80 year group, but that rural drivers aged over 80 years actually had higher rates than similarly aged urban drivers. Hanson and Hildebrand (2011b) therefore suggested that low mileage bias may not exist for older drivers in the rural context. This conclusion points to a degree of uncertainty regarding the comparative crash involvement rates of rural and urban older drivers and suggests that further research is needed.

Serious and fatal injury.

Despite having a lower crash rate, previous research has shown that drivers of all ages who live in rural areas are at a higher risk of serious or fatal injuries following a crash than drivers who reside in urban areas. This finding has been replicated in numerous parts of the world, including the USA (Borgialli, Hill, Maio, Compton, & Gregor, 2000; Brown, Khanna, & Hunt, 2000; Chen, Maio, Green, & Burney, 1995; Clark, 2003; Donaldson, Cook, Hutchings, & Dean, 2006; Kelleher, Pope, Kirby, & Rickert, 1996; Maio, Green, Becker, Burney, & Compton, 1992; Muelleman, Wadman, Tran, Ullrich, & Anderson, 2007;

Muelleman, Walker, & Edney, 1993; Zwerling, et al., 2005), the UK (Bentham, 1986), Canada (Kmet & Macarthur, 2006), and Australia (Du, Finch, Hayen, & Hatfield, 2007; Mitchell & Chong, 2010). Most recently, the National Highway Traffic Safety Administration (NHTSA, 2013a) reported that, in 2011, 19% of the population in the USA lived in rural areas, but fatalities from crashes in rural areas accounted for 55% of all traffic fatalities. It was also shown that, on a per 100 million miles travelled basis, the fatality rate in rural areas (1.82) was 2.5 times higher than in urban areas (0.73). Previous research has attributed the higher risk of serious or fatal injuries in rural crashes to various factors, including higher speed limits (Gonzalez et al., 2007), delays in the delivery of medical care after a road accident (Bentham, 1986; Brodsky & Shalom Hakkert, 1983; Clark, 2003; Leicht et al., 1986; Muelleman & Mueller, 1996), the reduced availability and quality of trauma medical care (Brodsky & Shalom Hakkert, 1983; Muelleman, et al., 2007), and greater alcohol usage (Borgialli, et al., 2000; Muelleman & Mueller, 1996) in rural areas.

It was noted in Chapter 1 that older drivers have an increased risk of serious and fatal injury resulting from crash involvement, compared to younger drivers (Baldock, 2004; Evans, 2000, 2001; Fildes, et al., 1994; Hanrahan, et al., 2009; Kahane, 2013; Langford & Koppel, 2006a; Meuleners, et al., 2006; Newgard, 2008; OECD, 2001; Rakotonirainy, et al., 2012; Ryan, et al., 1998). This results from the reduced tolerance of older adults to injury, compared to younger adults (Evans, 1988; Li, et al., 2003; Viano, et al., 1990; Viano, et al., 1989), and is likely to be greater if they live in rural areas. Two studies that have examined the high rate of motor vehicle crash deaths in rural areas of Michigan, USA, found an association between driver age and fatal crashes in rural areas, and that older drivers were more likely to be involved in rural crashes (Borgialli, et al., 2000; Maio, et al., 1992). However, they did not directly compare the serious injury and fatality rates of rural and urban older drivers, and their analyses only divided age into three groups (16-25, 26-50 and over 50). More comprehensive research has been undertaken in the USA by Zwerling et al. (2005) who examined the rates of

injuries of any severity (per 100 crashes), fatal crash incidents (per 100 million miles driven), and fatal injuries (per 1000 injury crashes) for various age groups from both rural and urban areas. Firstly, it was reported that all three rates, in both rural and urban areas, were highest for the oldest drivers (i.e. 85 years and over). Secondly, across all age groups, the rates were always higher in rural areas, compared to urban areas, with the largest rural and urban difference being in the 85 years and over age group. Thus, the study demonstrated that the rates of injury, including fatal injuries, were higher for older rural drivers compared to their urban counterparts. However, to date, no equivalent research has been undertaken in Australia to compare the fatality rates of rural and urban older drivers.

The increased risk of serious or fatal injuries for older rural drivers is likely to result from the tendency to be travelling at higher speeds when they crash (due to higher speed limits) or from the issues related to medical care in rural areas discussed earlier. However, other factors may be involved that have not previously been identified which, along with speed limits, could be adjusted to make rural driving environments safer for older drivers. For example, it has been suggested by Zwerling et al. (2005) that “increased crash severity on rural roads may occur because crash characteristics are different on rural than urban roads” (p.26-27). Indeed, previous research by Baldock, Kloeden and McLean (2008) has suggested that rural crashes are often characterised by the vehicle leaving its designated lane due to driver inattention, overtaking manoeuvres or road curvature, as well as a loss of control due to unsealed road surfaces and high travelling speeds. This can then lead to a head-on collision with another vehicle (lanes travelling in opposite directions are not divided on many rural roads in Australia), a collision with a fixed roadside object, or a vehicle rollover. Such crashes are likely to be more serious than those that commonly occur in urban areas, such as rear-end collisions. There may also be differences between rural and urban older drivers in relation to the environmental conditions that are present when they commonly crash, the errors that they make that result in the crash, or the age of the vehicles that they drive. Consequently, an

investigation of the environmental (e.g. weather conditions, road layout, speed limit), driver (e.g. driver error, crash type) and vehicle factors (e.g. vehicle age) that are associated with the crashes of older rural drivers compared to those associated with the crashes of older urban drivers may provide potential explanations for any differences in serious and fatal injury rates. It is important to gain a better understanding of any potential explanations for the increased serious and fatal injury risk for older rural drivers in order to identify the most effective countermeasures.

Furthermore, it would also be useful to measure and compare the extent to which both rural and urban older drivers are exposed to certain factors that may increase the likelihood of serious or fatal injury. For example, if older rural drivers are more likely to be seriously or fatally injured in a crash because they are also more likely to crash on high-speed roads, it would be useful to determine the extent to which they are exposed to these high-speed roads in their everyday driving, compared to older urban drivers. If they have a high level of exposure to high-speed road conditions that put them at risk, this may further explain why they may be more likely to be seriously or fatally injured in a crash than urban older drivers.

Summary of the safety of older rural drivers.

To summarise, research has indicated that older rural drivers may be involved in fewer crashes than older urban drivers (Foley, et al., 1995; Zwerling, et al., 2005). This may be due to the nature of rural driving environment, where there is less traffic and fewer potential conflict points (e.g. intersections) on roads, such as freeways, where a lot of the mileage may be accrued. However, other research has contradicted these findings by showing that, with increased age and mileage, older rural drivers may undertake an increased amount of driving in urban areas, where there is more traffic and more intersections (Hanson & Hildebrand, 2011b). Indeed, Hanson and Hildebrand (2011b) provided crash data which indicated that the oldest rural drivers (aged over 80 years) may actually have higher crash rates than their urban

counterparts. Therefore, further research that compares the crash rates of rural and urban older drivers is needed. Secondly, despite being involved in fewer crashes, it has been shown that older rural drivers are more likely to be seriously or fatally injured when they are involved in a crash (Borgialli, et al., 2000; Zwerling, et al., 2005). However, this has not previously been examined by research in an Australian context. Australia is a country that mostly consists of rural and remote regions (Rose, 1977) where long distances need to be travelled between destinations (Sayeg, 2005) on high-speed roads. Therefore, a comprehensive study of the crash, serious injury, and fatality rates of rural and urban older Australian drivers is needed. In addition, the increased likelihood of serious or fatal injuries for older rural drivers may result from certain environmental, driver and vehicle factors (e.g. crashing on a road with a speed limit of 100km/h or higher) that are more common in their crashes compared to those of older urban drivers. It is also likely that specific hazardous environmental factors, such as high speed roads with undivided lanes, are more common in the crashes of older rural drivers because these drivers have a higher level of exposure to them in their everyday driving. It is important to identify the factors that increase the risk of serious and fatal injury for older rural drivers, as well as the extent to which they are exposed to them, in order to adjust rural driving environments to make them safer for older drivers.

Mobility of Older Rural Drivers

Importance of driving to older rural adults.

Despite the potentially increased risk of serious and fatal injury for older rural drivers, equal consideration needs to be given to the importance of driving and maintenance of mobility in this group. People who live in rural areas are more reliant on driving (Mattson, 2013; Nutley, 2003), partly because necessary services (e.g. general practitioners and supermarkets) and lifestyle activities (e.g. visiting family or friends) tend to be further away than for urban dwellers and are only accessible by car.

Rural residents are also likely to be more reliant on driving because it has been shown that alternative means of transportation are often either limited or not available (Adler, et al., 1999; Corcoran, James, & Ellis, 2005; Johnson, 1995; Mattson, 2011; NCD, 2005; Nutley, 2003; Rosenbloom, 2004). Indeed, Corcoran et al. (2005) found that in Victoria, Australia, the number of older adults with access to public transport decreases according to how rural a given living area is, as determined by the Accessibility Remoteness Index of Australia (ARIA). In the USA, figures from the National Council on Disability (2005) suggest that approximately 40% of the rural population has no public transportation at all, and another 25% only has minimal services. Urban residents have access to 25 times more public transportation service than rural residents (NCD, 2005). A study by Johnson (1995) in the USA also found that family and friends of older rural residents are likely to live further away and, therefore, be less available to provide transport. These factors are likely to have played a part in the findings of Peel et al. (2002) who found that rural participants in Queensland, Australia (who were aged 75 years and over) reported driving to be the only option consistently available to them.

It is not surprising, therefore, that research in the USA has demonstrated that vehicle ownership is higher amongst rural residents (of all ages), compared to urban residents (Mattson, 2013; Pucher & Renne, 2005). Mattson (2013) indicated that 96% of rural households have access to a vehicle, compared to 89% of urban households. Research by Nutley (2003) reported that vehicle ownership is also higher amongst rural residents in Australia (93% of households in rural south eastern states compared to 88% Australia-wide), as well as in the United Kingdom, and has suggested that “the problems of distance, and rural isolation are apparently ‘solved’ by very high car ownership” (p.68). Moreover, Mattson (2013) also showed that a larger proportion of the travel of rural residents is undertaken by car compared to urban residents (90% compared to 84%), but a smaller proportion of their travel is undertaken by public transport (0.4% compared to 2.9%). Pucher and Renne (2005) have

found that this is also the case for drivers aged 65 years and older, although the difference between rural and urban drivers is smaller for this age group (92% vs. 89% for travel by car and 0.1% vs. 1.3% for travel by public transport). Thus, it seems that accessibility in rural areas is contingent upon the use of a personal motor vehicle (Nutley, 2003; Pucher & Renne, 2005). Pucher and Renne (2005) have suggested that the car is essentially the only way that people get around in rural areas.

Consequences of driving cessation for older rural adults.

One consequence of the increased dependence of older rural adults on their car and the ability to drive, is that they may be more reluctant to stop driving; possibly viewing driving cessation as impossible or too detrimental to their mobility. Research by Mattson (2013) showed that the proportion of drivers aged 65 and over who drive is higher in rural areas of the USA (93% of males and 82% of females) compared to urban areas (87% of males and 71% of females). As a result, many older rural drivers may hold onto their licences, despite knowing or having been advised that they are no longer fit to drive (Johnson, 2002).

For those older rural drivers who have to stop driving, the consequences of this change are likely to be especially detrimental. As noted in Chapter 1, the mobility that driving provides to older drivers is particularly important to their independence, convenience, self-worth, social networks and active lifestyles (Adler, et al., 1999; Peel, et al., 2002; Whitehead, et al., 2006). Moreover, when older adults cease driving their mobility, lifestyle and health can be greatly affected (Bonnel, 1999; Edwards, et al., 2009; Marottoli, et al., 2000; Marottoli, Mendes de Leon, et al., 1997; Peel, et al., 2002; Rosenbloom, 2001). These effects may be greater for older adults from rural and remote areas who have to stop driving. Research by Johnson (1995) found that driving cessation caused feelings of isolation in older rural adults. Also, older rural drivers who participated in research by Hanson and Hildebrand

(2011c) reported that they would no longer undertake 36% of their usual trips if they did not have access to a vehicle.

Effect of living in rural or remote areas on the mobility of older drivers.

In addition to the effect on the mobility of older adults who have to stop driving, the longer distances that need to be travelled in rural areas may restrict the mobility of current drivers in terms of their access to everyday lifestyle activities. It has been shown that rural drivers of all ages travel, on average, a larger distance per individual trip, per day, and per year than urban drivers (Mattson, 2013; Pucher & Renne, 2005). Research in the USA by Pucher and Renne (2005) demonstrated that, for all age groups combined, people in rural households covered 38% more distance per day than those in urban households, with rural drivers aged 80 to 84 years covering 62% more distance per day than their urban counterparts and those aged 85 and over covering 51% more. Consequently, the longer distances that need to be driven in rural areas may reduce the ease with which older drivers can reach desired destinations, which may result in a reluctance to make any more trips than are absolutely necessary. Indeed, a study by Hough, Cao and Handy (2008), which surveyed the travel patterns of elderly women (aged 65 years and older) in rural North Dakota, USA, found that they tended to make fewer trips in general than older women living in small urban areas. Consistent with Hough et al. (2008), other research from the USA by Mattson (2013) indicated that the average number of trips that rural drivers aged 65 to 74 make per day is slightly lower than their urban counterparts (3.5 trips compared to 3.7). However, it was also shown that rural drivers aged 75 and older made the same number of trips per day, on average, as urban drivers of the same age (2.7 trips). This differential between younger-elderly drivers and older-elderly drivers is more pronounced in the research by Pucher and Renne (2005), who found that rural drivers aged 65 to 79 made fewer trips per day than their urban counterparts (an average of 3.3 compared to 3.6), but those aged 80 and over actually

made slightly more trips (an average of 2.5 compared to 2.4). Thus, there are differing findings from past research regarding this issue.

There is more to individual mobility, however, than just the number of trips that a person undertakes. A recent definition of mobility provided by Nordbakke (2013) states that it is “the ability to choose where and when to travel and which activities to participate in outside the home in everyday life” (p.166). The ability to choose may be restricted for older rural drivers because they may have to prioritise their driving and, potentially, neglect activities that are discretionary in nature, such as leisure, social and community activities. Consistent with this, Hough et al. (2008) showed that rural older women travel less than older women from small urban areas particularly for certain trips, such as going to a restaurant, a friend’s house, a store, a hair salon, or an exercise place. However, research from Canada by Hildebrand, Gordon, and Hanson (2004), which examined the travel behaviour of rural and urban drivers aged 65 and over, indicated that older rural drivers undertake more trips than older urban drivers for the purposes of socialising and eating out. Therefore, once again, the findings differ. Moreover, this phenomenon has not previously been examined in an Australian context, where the distances that need to be travelled between destinations in rural areas are vast and may further increase the difficulty of travel and the need to prioritise driving. Given the importance of mobility to the health and well-being of older adults, as mentioned earlier, it would seem important to determine conclusively whether the everyday mobility of older rural drivers is restricted in comparison to their urban counterparts.

Summary: mobility of older rural drivers.

Driving is fundamental to the everyday lives of older rural adults because it may be the only way in which they can reach their desired destinations and alternative means of transportation are often either limited or not available in rural areas (Corcoran, et al., 2005; Johnson, 1995; Mattson, 2013; NCD, 2005; Nutley, 2003). As a result, older adults from rural

areas may be more reluctant to give up driving than older adults from urban areas because the effects on their mobility, lifestyles and health may be greater. Furthermore, the circumstances of living in rural areas may also restrict the mobility of current older drivers. In particular, the longer distances that need to be travelled in rural areas in order to reach their destinations may lead older drivers to limit the number of trips that they make or prioritise their driving by making less trips for discretionary activities (e.g. leisure, social and community activities) (Hough, et al., 2008; Mattson, 2013). There has only been limited research into these issues and no research has been undertaken in an Australian context. As mentioned earlier, Australia is a country which mostly consists of rural and remote regions (Rose, 1977) where small populated areas are separated by vast distances. It is important, in addition to investigating whether older rural drivers have an increased risk of serious and fatal injury, to investigate whether their everyday driving mobility is affected by living in rural or remote areas. In order to compare the mobility of rural and urban older drivers, it would be useful to examine the amount that they drive (i.e. distance, time, number of trips, etc.), as well as the activities that they undertake through their driving (both discretionary and non-discretionary).

Self-Regulation by Older Rural Drivers

Chapter 1 described the practice of self-regulation, whereby an older driver assesses their own abilities and adjusts their driving accordingly to reduce the risk of crash involvement, either through a reduction in the amount of driving they do or by avoiding difficult driving situations. By self-regulating their driving, older adults may be able to both manage their own safety on the road and maintain some degree of driving mobility. This practice may be particularly beneficial for the safety of older drivers from rural areas, given that they may have a higher risk of being seriously and fatally injured in a crash. It may also be particularly useful as a strategy for continuing to drive and maintaining mobility, given

that the consequences of driving cessation are likely to be even more detrimental for older rural drivers.

However, older rural drivers may find it more difficult to self-regulate their driving compared to older urban drivers for several reasons. Firstly, as mentioned, driving is likely to be more important for accessing necessary community services (e.g. doctor, supermarket) and for maintaining their community involvement because these services are often further away than for urban dwellers and only accessible by car. Consequently, they may be less willing to reduce or avoid driving, as it would have a greater effect on their independence and lifestyle than would be the case for older urban adults who have shorter distances to travel in order to access community services. Previous research has provided some support for this. For example, Mattson (2011) surveyed persons (aged from 50 to 97 years old) living in rural and small urban areas of North Dakota, USA, in order to examine the issues of ageing and mobility and found that individuals who travelled longer distances to get to their destinations were less likely to avoid driving during certain conditions, including winter, when it was raining, and when it was dark outside.

A second reason why self-regulation may be more difficult is that, as discussed, access to alternative transportation - such as public transportation (Corcoran, et al., 2005) and friends and family (Johnson, 1995) - is often more limited in rural areas. Other transport options, such as community buses and taxis, are also less likely to be available, further increasing the importance of driving in order to maintain the lifestyle of older rural adults. Past research has indicated that adequate alternative transportation is needed for older adults to voluntarily reduce or avoid driving. Stalvey and Owseley (2000) surveyed a sample of older drivers (aged between 60 and 91) from Alabama, USA, who had been involved in a crash in the previous year and found that 75% thought that the lack of adequate public transportation made it impossible to change when and where they drove. Also, 57% thought that the lack of family and friends who were available to provide transport for them made self-regulation impossible

and 54% thought that their lifestyle, and the places that they need to go, would not allow it. Research by Choi, Adams, and Kahana (2013) surveyed a sample of older drivers (aged between 71 and 94) from Florida, USA, and reported that those who received transport support from friends were more likely to avoid driving at night and on a highway than those with little or no support. Thus, given that alternative options are less available in rural areas, compared to urban areas, older rural drivers may adopt fewer self-regulatory practices than their urban counterparts.

Other research by Hanson and Hildebrand (2011a) examined the driving exposure and travel patterns of a sample of rural Canadian drivers, aged 54 to 92 years, using both GPS-based and self-report methods to collect data. This study found that older rural drivers do avoid some difficult driving situations, such that 50% of the sample did not drive after dark and 40% drove less than one per cent of their total surveyed kilometres on major highways. Furthermore, the proportion of participants taking night trips and traveling on major highways decreased with age. However, the actual extent to which older rural drivers self-regulate their driving (by avoiding a range of specific difficult driving situations, reducing their overall driving, and being willing to stop driving if necessary), compared to older urban drivers, has not previously been examined. Moreover, it is not currently known whether the ability of older rural drivers to self-regulate is restricted by the increased importance they attribute to driving and their reduced access to alternative transportation. Thus, additional research is needed to examine the perceptions of rural and urban older drivers regarding the importance of driving for meeting their day-to-day needs, the availability of alternative transportation, and the extent to which they self-regulate their driving.

Summary: Safety and Mobility of Older Rural Drivers

In conclusion, the competing demands of safety and mobility may be particularly problematic for older drivers who live in rural areas. Continuing to drive and remain mobile

are very important for older rural adults but, at the same time, the circumstances of driving in rural areas may both increase risk on the road and restrict their mobility. In terms of risk on the road, they may have an increased likelihood of being seriously or fatally injured when involved in a crash, compared to older urban drivers (Borgialli, et al., 2000; Zwerling, et al., 2005). Certain environmental, driver and vehicle factors that may be more common in the crashes of older rural drivers (e.g. crashing on a road with a speed limit of 100km/h or higher) may contribute to this increased likelihood of serious or fatal injury. Furthermore, it is likely that certain hazardous environmental factors (e.g. high speed roads with undivided lanes) are more common in the crashes of older rural drivers because these drivers have a higher level of exposure to them in their everyday driving. In terms of mobility, the longer distances that older rural drivers have to travel to reach their destinations, compared to older urban drivers, may restrict their ability to undertake everyday lifestyle activities, particularly activities that are discretionary in nature (Hough, et al., 2008; Mattson, 2013). Self-regulation provides an option for older drivers to both improve their safety on the road and maintain driving mobility. This practice may be particularly beneficial for older rural drivers, given that they may have a higher risk of being seriously and fatally injured in a crash. However, their ability to self-regulate their driving may be restricted by the importance they attribute to driving and the availability of alternative transportation in rural areas.

Aims of the Current Research

Based on the literature that has been reviewed, further research into the safety and mobility of older rural drivers is needed. The current research was designed to do this through five independent studies that examined the safety and mobility of older drivers who live in rural or remote areas of South Australia, compared to their urban counterparts. The state of South Australia covers a large area of land: 984,160 km² (Boshoff & Hartshorne, 2008). Most of this land is rural or remote and is characterised by small towns separated by vast distances

(Gay, Herriot, & May, 1995). In addition, figures from the South Australian Department of Planning, Transport and Infrastructure for the year 2009 indicate that a large proportion (28%) of licensed drivers aged 65 years and older who are entitled to drive non-commercial motor vehicles (not exceeding 4,500kg) in South Australia reside in rural areas. Therefore, research that examines the safety and mobility of older rural drivers in South Australia is important.

The specific objectives of the five studies outlined in the next five chapters were to:

1. Examine the crash, serious injury, and fatality rates of various age groups from both rural and urban areas of South Australia (Study 1, Chapter 3). To this end, a database of police-reported road crashes in South Australia - the Traffic Accident Reporting System - was used to obtain crash, serious injury, and fatality data for the years 2004 to 2008. It was predicted that older drivers, defined as 65 years and older, would have lower *crash rates* but higher rates of *serious or fatal injury* than drivers who were aged 16 to 64 years, and that older rural drivers would have higher rates of serious or fatal injury than older urban drivers.

2. Examine the environmental, driver and vehicle factors that are involved in the crashes of older drivers from rural and urban areas of South Australia, as well as the relationship between these factors and serious or fatal injuries (Study 2, Chapter 4). The crash, serious injury, and fatality data from the Traffic Accident Reporting System were again used to undertake this study. It was predicted that the environmental, driver and vehicle factors that were more common in the crashes of older rural drivers (e.g. roads with a speed limit of 100km/h or higher) would increase the likelihood that the driver involved in the crash would be seriously or fatally injured.

3. Examine the perceptions of older drivers from rural and urban areas regarding: the importance of driving, their access to alternative transportation, and the degree to which they self-regulate their driving (Study 3, Chapter 5). A sample of older drivers from rural ($N = 64$) and urban ($N = 106$) areas of South Australia completed a questionnaire on driving importance, alternative transportation, and driving self-regulation. It was predicted that older rural drivers would view driving as more important than the urban participants and would believe that they have fewer alternative transportation options available to them (e.g. taxis). It was also predicted that older rural drivers would report that they self-regulate their driving less than older urban drivers and that this was as a result of the increased importance of driving to them, as well as their reduced access to alternative transportation.
4. Evaluate the use of both objective - Global Positioning System data loggers - and subjective - self-report telephone-based travel diaries - methods for measuring the driving exposure and travel patterns of older road users (Study 4, Chapter 6). A sample of drivers from rural ($N = 28$) and urban ($N = 28$) areas of South Australia (who were a sub-sample of the 170 drivers in Study 3) had their driving monitored for a period of one week using these data collection methods. It was thought that the combination of these data collection methods would provide accurate information relating to driving exposure and travel patterns for all participants. A subset of the participants ($n = 16$) were also interviewed to provide feedback regarding the data collection process.
5. Examine driving mobility, in terms of access to discretionary and non-discretionary lifestyle activities, and exposure to risk, in terms of intersections (potential conflict points) and high-speed driving environments, for older drivers from rural and urban

areas of South Australia (Study 5, Chapter 7). This was achieved by analysing the driving exposure and travel pattern data collected for Study 4. It was predicted that older rural drivers would drive longer distances than older urban drivers but would be more restricted in their everyday driving mobility, making fewer trips and undertaking fewer discretionary activities. It was also predicted that rural and urban older drivers would differ in their exposure to risk, in that older rural drivers would encounter fewer intersections in their driving, but would drive further, and for longer periods, on roads that have speed limits of 100 km/h or higher and at GPS-measured speeds of 100km/h or faster.

Chapter 3: Study 1

Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates.

This chapter consists of a published paper, but copyright restrictions prevent the reproduction of this paper in its published form. The details of this publication are:

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2010). *Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010672.pdf>

This study was peer-reviewed and published as part of the proceedings for the 2010 Australasian Road Safety Research, Policing and Education Conference held in Canberra, Australia. The author of this thesis (James Thompson) gave a 20-minute presentation of this study at the conference. The study was awarded the 2010 John Kirby Memorial Road Safety Award for the best paper by a new researcher at the conference.

Preamble

The preceding chapters reviewed the literature relating to the road safety and mobility of older drivers, in general, and then more specifically relating to older drivers who live in rural and remote areas. In terms of the safety of older drivers, generally, it was reported that they have fewer overall crashes than drivers in younger age groups and have fewer crashes even after controlling for decreases in the number of people and rates of licensure that occur in older age groups. In contrast, on a per kilometre driven basis, they have an elevated crash risk and an increased risk of being seriously or fatally injured from the crashes in which they are involved. With respect to the safety of older rural drivers, it was thought that their risk of serious or fatal injury would be further increased by the circumstances of living in rural areas (e.g. longer distances to travel, more roads with high speed limits). However, no previous research has undertaken a comprehensive evaluation of the crash, serious injury, and fatality rates of older rural drivers in comparison to older urban drivers.

Consequently, the first stage of this research was to complete such an investigation. To this end, the following study involved the analysis of five years (2004 to 2008) of crash, serious injury, and fatality data for drivers of various age groups from both rural and urban areas of South Australia. It was predicted that older drivers (65 years and older) would have lower crash rates but higher rates of serious or fatal injury than drivers aged 16 to 64 years, and that older rural drivers would have higher rates of serious or fatal injury than older urban drivers.

**Older drivers in rural and urban areas: Comparisons of crash, serious injury, and
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The authors would also like to express their gratitude to the following people from the Centre for Automotive Safety Research: Jamie Mackenzie for making the TARS data available and Jaime Royals for acquiring the population and licensing data.

Abstract

Previous analyses of crash statistics have indicated that older drivers (aged 65 years and older) have fewer crashes than other age groups. However, they have an elevated crash risk on a per kilometre driven basis and are at an increased risk of death and serious injury from crashes. Older drivers living in rural areas may be particularly at risk due to a greater dependence on driving, which may create a reluctance to cease driving. It is often demonstrated that motor vehicle crash fatality rates are higher in rural areas than urban areas. However, more research that compares the crash, serious injury, and fatality rates of rural and urban older drivers is required. A database of police-reported road crashes in South Australia, the Traffic Accident Reporting System, was used to obtain crash, serious injury, and fatality data for 2004 to 2008. The crash involvement of drivers of various age groups from both rural and urban areas was adjusted for population and licensure exposure measures. Crashes involving rural drivers aged 75 and over were more likely to have resulted in a serious or fatal injury than crashes involving their urban counterparts. The results indicate that rural older drivers present a unique road safety problem.

Keywords: older drivers, crash rate, rural areas, urban areas, fatality, serious injury

Research investigating the crash risk of older drivers (here defined as persons aged 65 years and older) has demonstrated that crash numbers decline with age (Baldock, 2004; Ryan, et al., 1998)⁴. In fact, drivers over the age of 65 have a lower number of crashes than all other age groups. Even after controlling for decreases with age in population and rates of licensure, older drivers still have fewer crashes. Older drivers also drive fewer kilometres, on average, than drivers from other age groups, which may account for their low crash numbers. Indeed, when controlling for the number of kilometres driven, studies have demonstrated that older drivers have an elevated crash risk on a per kilometre driven basis, which is second only to the very youngest age groups.

In addition to this elevated crash risk per distance driven, older drivers are at an increased risk of death (Hanrahan, et al., 2009) and serious injury (Baldock, 2004; Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meulenens, et al., 2006; Ryan, et al., 1998) from crashes in which they are involved. This is attributed to increased fragility with older age (Li, et al., 2003). In support of this, Hanrahan et al. (2009) have demonstrated that drivers aged 85 years and older were greater than five times more likely to experience a moderate or severe injury than those aged 25 to 44 and are the age group most likely to die or to suffer an injury in a crash.

The crash, serious injury and fatality risk of older adults in rural areas may be greater than that of urban older drivers because they may be less able to reduce or cease driving when they are no longer fit to drive. This may be due to several reasons. First, public transport is generally less available or not available at all. Indeed, Corcoran et al. (2005) found that in Victoria, Australia the proportion of older drivers with access to public transport decreases as rurality increases. Second, family and friends are likely to live further away and, therefore, be less available to provide transport (Johnson, 1995). Finally, necessary services, such as

⁴ Each published paper that appears in this thesis was originally prepared according to the referencing style that was required for the journal or conference in which it was published. However, this thesis is formatted throughout according to the American Psychological Association's (APA) Publication Manual (2010) in order to maintain consistency.

general practitioners and supermarkets, are often further away and only accessible by car. Therefore, older adults who live rurally are more dependent on the car and the ability to drive to meet their mobility requirements. Consequently, rural older drivers may have a greater crash risk.

Past research has shown that motor vehicle crash death rates, in general, are higher in rural areas than urban areas (Borgialli, et al., 2000; Brown, et al., 2000; Donaldson, et al., 2006; Maio, et al., 1992; Muelleman, et al., 2007), which has been attributed to higher speed limits (Gonzalez, et al., 2007), delayed medical care (Muelleman & Mueller, 1996), reduced availability of medical care (Muelleman, et al., 2007), and alcohol use (Borgialli, et al., 2000). With regard to age, two studies (Borgialli, et al., 2000; Maio, et al., 1992) examining motor vehicle crash deaths in rural areas of Michigan, USA found an association between driver age and fatal crashes in rural areas and that older drivers were more likely to be involved in rural crashes. However, they did not directly compare the serious injury and fatality rates between rural and urban older drivers, and their analyses only examined three age groups (16-25, 26-50 and over 50). Therefore, further research is required to comprehensively compare the crash, serious injury and fatality rates of rural and urban older drivers to determine whether they are higher for rural older drivers. The current research was designed to meet this need.

This study examined the crash involvement (total crashes, crashes per head of population and per licensed driver) of rural and urban drivers separately, and compared the likelihood of a serious injury or fatality from a crash for rural and urban older drivers. Based on the literature, it was hypothesised that older drivers (65 years and older) would have lower crash rates but higher rates of serious or fatal injury than drivers aged 16 to 64 years, and that rural older drivers would have higher rates of serious or fatal injury than urban older drivers.

Method

Materials

Crash data for the years 2004 to 2008 inclusive were obtained from the Traffic Accident Reporting System (TARS), which is a database of all police-reported road crashes in South Australia managed by the Department for Transport, Energy and Infrastructure (DTEI). For a crash to be included in TARS, at least one of the participants must have been injured, \$3000 or more worth of damage caused, or one of the vehicles towed away. If any of these criteria are fulfilled, the participants are required to report the crash to the police.

Population data for South Australia were obtained from the Australian Bureau of Statistics (ABS). These data were organised by age and rural or urban area (as defined by the statistical local area and postcode)⁵ from 2004 to 2008. From these data, the average annual population over the five years for each age group across both areas was calculated. This was then used to calculate the crash rate per head of population for all age groups in both living areas.

DTEI provided data on driving licensure, which were used to estimate the number of licensed drivers in South Australia by age and postcode of the individual so that crash rates on a per licensed driver basis could be calculated for rural and urban areas. Ideally these data would have been obtained for the years 2004 to 2008 so that a yearly average over the five years could be calculated, but data were only available for 2009. An estimate of the number of licensed drivers that is based on data from the year subsequent to the time period of interest is likely to introduce some bias to the results but was expected to be minimal, given that the difference in amount of licensure would be relatively small.

⁵ Urban and rural areas were differentiated on the basis of a classification of South Australia postcodes, used by Kloeden (2008), whereby urban areas were defined as the capital city, Adelaide, and regions within a 5 to 20 kilometre radius of the central business district. Rural areas were defined as those regions outside of the urban area.

Procedure

The variables in the TARS database that were extracted were age, postcode of the driver, crash injury severity and driver injury severity. The postcode of the driver was used to determine whether he or she lived in a rural or urban area of South Australia. Crashes where the driver lived interstate or where the postcode was not known were excluded. Crash injury severity refers to the degree of injury incurred by the most severely injured participant (vehicle occupant or pedestrian) involved in the crash and has five levels of severity: 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. Driver injury severity has the same five levels of severity but refers to degree of injury incurred by the driver. For the purposes of this research, a serious injury was defined as admission to hospital. Data from TARS are particularly useful because property damage only crashes are included. This provides a much more detailed picture of the extent of overall crash involvement in comparison to databases that only include injury crashes.

Age was divided into the following groups: 16-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, and 85 and over. For present purposes, drivers aged 65 and older were labeled “older drivers”. An individual cannot obtain a driver’s licence in South Australia until they are 16 years of age. There were, however, crashes recorded in the TARS database in which the age of the driver was less than 16, suggesting that these individuals were unlicensed and driving illegally at the time. Consequently, these crashes were included in the initial assessment of total crash involvement but excluded from subsequent analyses.

It was necessary to use data from TARS that related to crash-involved drivers rather than the crashes themselves in order to examine the age of the drivers involved in crashes. One of the consequences of using these data is that, for crashes involving multiple drivers, each driver would have a separate entry in the database. Therefore, a single crash that involved more than one driver would represent multiple crashes. Crashes were only included

in this study if the crash-involved driver was driving a car or similar vehicle (e.g. utility, panel van, station wagon). Car drivers were deemed to be of central interest in this study because the characteristics of crashes involving drivers of other vehicles (e.g. taxis, trucks, etc.) may be fundamentally different.

Results

The crash sample in this study was very large. Therefore, the common technique of analysing frequency data, using chi-square analyses, would be likely to find small group differences statistically significant, while meaningful significance (i.e. a substantial road safety issue) would be minimal. Thus, a comparison of frequencies and 99% confidence intervals was used instead. Statistical significance was determined at the $p < .01$ level by assessing any overlap of confidence intervals. If there was no overlap between the groups being compared they were considered to differ significantly. A conservative alpha level of .01 was used in order to protect against the increased likelihood of Type I errors resulting from multiple comparisons and to maintain a consistent alpha level across all analyses.

Crash rates

There was a total of 157,312 South Australian drivers of passenger vehicles who were involved in crashes in South Australia that were reported to the police in the years 2004 to 2008. In 149,729 (95.2%) of these, the age of the driver was recorded.

Table 1 illustrates the total number of crashes by age group in both rural and urban areas, and reveals that they decline with each successive age group (excluding those under 16 years of age, as they are not licensed drivers). Additionally, for all age groups, urban drivers have a larger number of crashes than rural drivers.

Table 1
Number of Crash-Involved Drivers by Age for Rural and Urban Areas of South Australia for the Years 2004 to 2008

Age Group	Rural Number of Crashes	% (where age known)	Urban Number of Crashes	% (where age known)
<16	27	0.1	81	0.1
16-24	8,013	31.0	34,076	27.5
25-34	4,594	17.8	26,149	21.1
35-44	4,392	17.0	23,145	18.7
45-54	3,699	14.3	18,531	15.0
55-64	2,533	9.8	11,563	9.3
65-74	1,411	5.5	5,783	4.7
75-84	930	3.6	3,818	3.1
85 +	221	0.9	763	0.6
Unknown	757	-	6,826	-
Total Known	25,820	100.0	123,909	100.0
Total	26,577		130,735	

In order to understand better the crash rates by age of urban and rural drivers, it was necessary to examine their rates on a per head of persons of that age in the population. This was achieved by dividing the number of crashes by the number of people in each age group (5 year average, 2004 to 2008) for rural and urban areas. Table 2 displays the 5 year average (2004 to 2008) population numbers for each of the age groups for rural and urban areas and illustrates that, for both areas, the largest population group is for middle age and numbers then steadily decrease into the older age groups. Figure 1 additionally displays the percentages of the population in each age group across both areas who were involved in a crash between 2004 to 2008. This shows that the crash rates decline with increasing age in both areas and that older drivers are under-represented in crash involvement when the data are adjusted for population numbers. Additionally, it can be seen that, except for the 85+ age group, urban drivers have a higher level of crash involvement on a per head of population basis.

Table 2
Rural and Urban Population by Age Group (Aged 16 and Over, 5 Year Average 2004 to 2008) for South Australia

Age Group	Rural (n)	%	Urban (n)	%
16-24	43,711	13.3	147,649	15.9
25-34	46,796	14.2	153,099	16.5
35-44	60,541	18.4	165,127	17.8
45-54	61,216	18.6	160,828	17.3
55-64	52,650	16.0	129,262	13.9
65-74	34,704	10.5	84,042	9.0
75-84	22,545	6.8	65,227	7.0
85+	7,556	2.3	23,631	2.5
Total	329,719	100.0	928,865	100.0

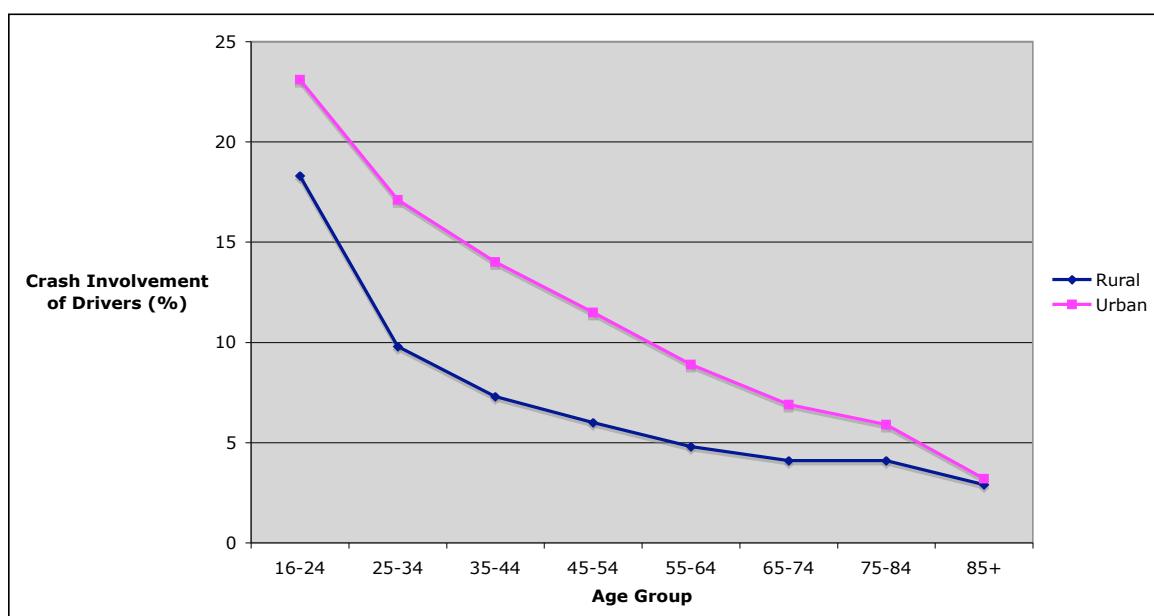


Figure 1. Proportion of rural and urban population (based on 5 year averages of population, 2004 to 2008) who were drivers involved in crashes by age group, South Australia.

Table 3 presents the number of licensed drivers in each age group for rural and urban living areas in 2009 and shows that licensure decreases markedly over the age of 64. Therefore, to understand better the crash rates for different age groups, it is also important to examine crash rates on a per licensed driver basis. To do this, the number of crashes was divided by the number of licensed drivers in 2009 for each age group across both areas.

Figure 2 presents the percentages of licensed drivers in each age group across both areas who were involved in a crash between 2004 and 2008. In the 16 to 64 age groups, these crash rates per licensed driver display a similar trend as the per head of population rates, in that they

decline with each successive age group. However, in the older age groups (65 and over), especially in rural areas, the rates level out and even begin to slightly increase. Additionally, it can be seen that urban drivers have a higher level of crash involvement on a per licensed driver basis across all age groups.

Table 3

Number of Licensed Drivers in South Australia, 2009, by Age Group and Living Area

Age Group	Rural (n)	%	Urban (n)	%
16-24	36,822	16.5	115,409	15.8
25-34	33,114	14.8	133,704	18.3
35-44	39,166	17.5	137,524	18.8
45-54	39,334	17.6	130,836	17.9
55-64	33,959	15.2	106,829	14.6
65-74	23,767	10.6	62,882	8.6
75-84	14,175	6.3	35,921	4.9
85+	3,063	1.4	7,443	1.0
Total	223,400	100.0	730,548	100.0

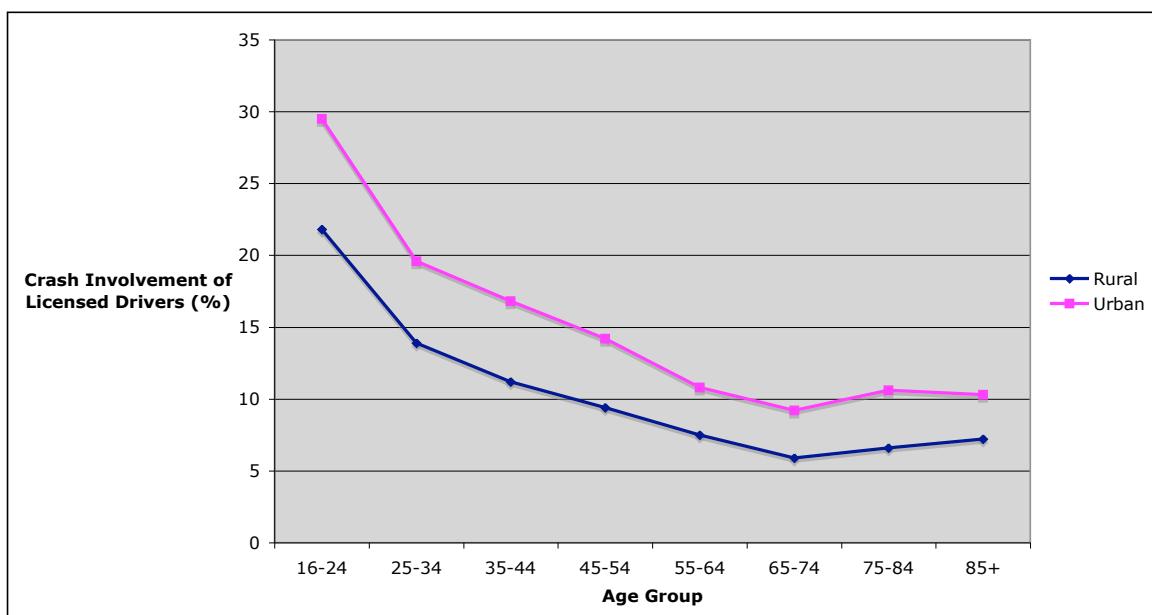


Figure 2. Percentage of rural and urban licensed drivers involved in crashes by age, South Australia.

Note. The number of licence holders is based on 2009 figures while the number of crashes is based on a 5 year average over 2004 to 2008.

Crashes involving serious or fatal injury

The hypothesis that crashes involving older drivers would be more likely than crashes for drivers aged 16 to 64 to have resulted in a serious or fatal injury (according to crash injury

severity) was assessed by calculating the proportion of serious or fatal injury crashes for each age group separately for rural and urban areas.

Figure 3 illustrates a trend in which, for both rural and urban areas, the proportion of serious crash involvement generally declines slightly with age, reaching a low around middle adulthood (i.e. the 45-54 and 55-64 age groups), but begins to increase to the highest levels in older age. For rural drivers, there is an overlap of the confidence intervals for all age groups, despite the trend being in the expected direction. Thus, rural older drivers are not statistically significantly more likely than drivers aged 16 to 64 to be involved in serious crashes. However, for urban drivers, the 75 to 84 and 85+ groups are significantly more likely to be involved in serious crashes than the other age groups. Additionally, except for the 85+ age group, rural drivers have higher percentages of serious or fatal injury resulting from crashes than urban drivers.

Figure 3 indicates that, at least for urban areas, the difference in the likelihood of serious or fatal injury between older drivers and drivers in younger age groups exists predominantly between drivers aged 75 years and above and those aged 16 to 74. Therefore, although drivers aged 65 years and older have conventionally been categorised as “older drivers”, it appears that, in this study, drivers aged 75 and older are the older drivers of particular interest when investigating the likelihood of serious or fatal injuries resulting from a crash.

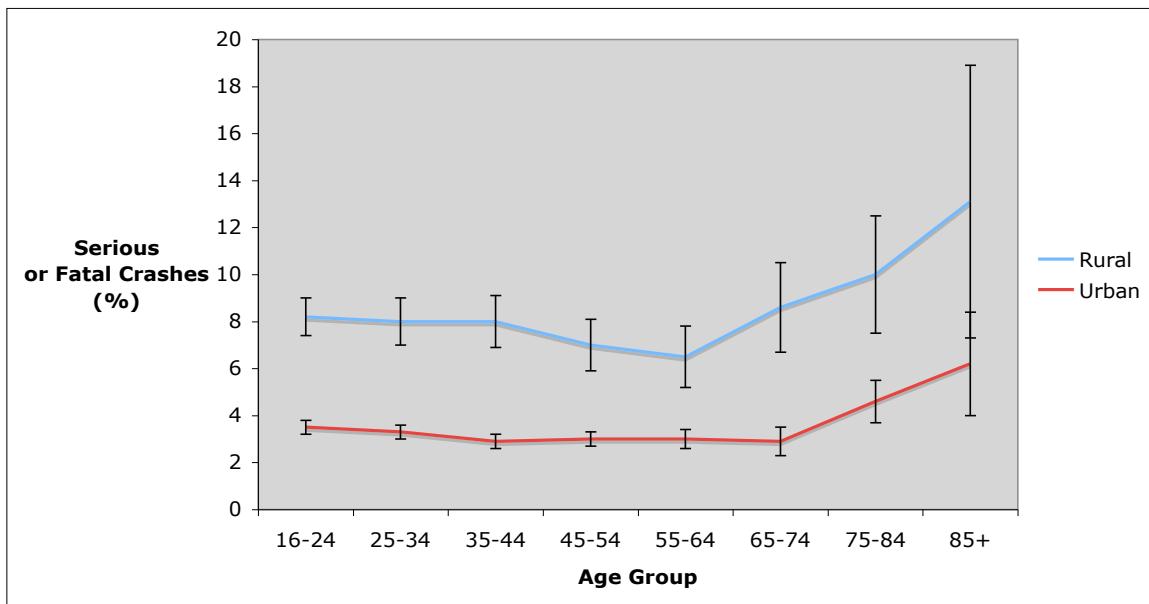


Figure 3. Percentage of serious or fatal injury crashes by age group and residential location of the driver (rural or urban) for the years 2004 to 2008, South Australia.

Note. Confidence intervals are illustrated by the black lines.

Consequently, the hypothesis that crashes involving rural older drivers would be more likely than those for urban older drivers to have resulted in a serious or fatal injury was assessed by using the figures for drivers aged 75 years and over instead of for 65 years and over. The percentage of serious or fatal crashes involving a rural driver aged 75 and over (10.6%, 99%CI = 8.3-12.9) was more than double that for urban drivers aged 75 and over (4.8%, 99%CI = 4.0-5.6), as illustrated in Figure 4. In addition, serious or fatal crash involvement was compared for rural and urban drivers aged 16 to 74. The serious or fatal crash involvement for drivers aged 16 to 74 in both rural (7.8%, 99%CI = 7.4-8.2) and urban (3.0%, 99%CI = 2.9-3.1) areas were significantly lower than the corresponding crash involvement for drivers aged 75 and over. As there is no overlap in any of the confidence intervals, this indicates that living rurally and being aged 75 and over both lead to a significantly greater likelihood that a serious or fatal injury will result when involved in a crash. The effect of location, however, is stronger than age.

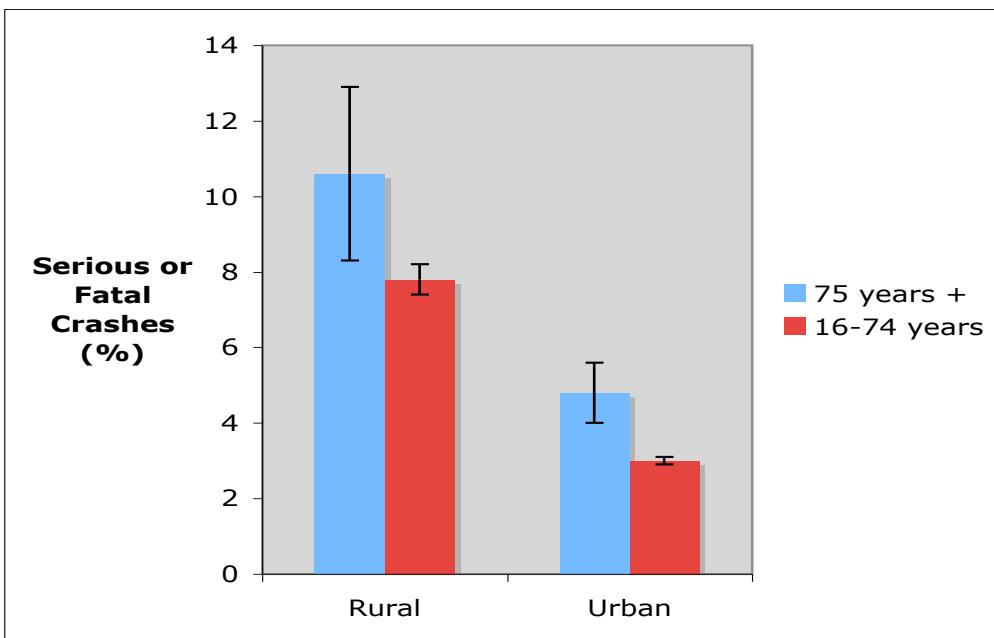


Figure 4. Comparison of the serious or fatal crash involvement of older drivers (aged 75 and over) and drivers aged 16 to 74 by residential location of the driver (rural and urban) for the years 2004 to 2008, South Australia.

Note. Confidence intervals are illustrated by the black lines.

The percentage of serious or fatal injury to rural and urban *drivers* in each age group is shown in Figure 5. There is a general trend in which, for both rural and urban drivers, the percentage steadily declines with age until older age when it begins to increase to the highest levels. For rural drivers the confidence intervals overlap so that only the oldest driver group (85+) and the two middle age groups (45-54 and 55-64) are statistically different from each other. For urban drivers, the 75 to 84 and 85+ groups are significantly more likely to be seriously injured or killed than the other age groups. Additionally, except for the 85+ age group, rural drivers have higher percentages of crashes where the driver was seriously or fatally injured than urban drivers.

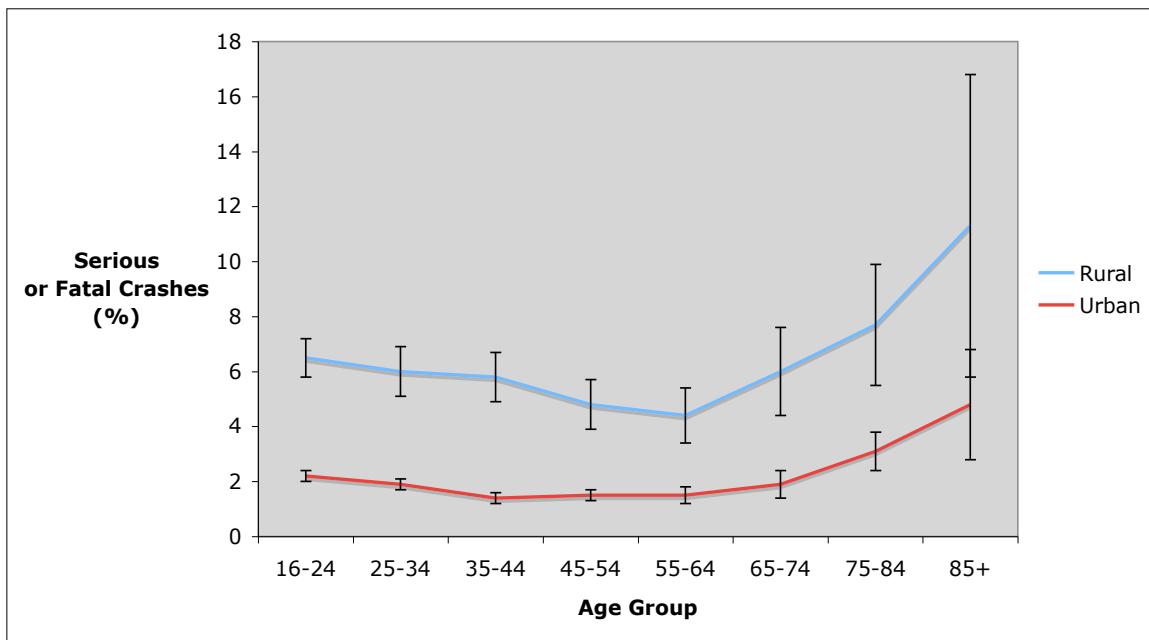


Figure 5. Percentage of rural and urban drivers seriously injured or killed by age group for the years 2004 to 2008, South Australia.

Note. Confidence intervals are illustrated by the black lines.

Figure 5 indicates that the difference in the likelihood of older drivers being seriously or fatally injured in crashes compared to drivers in younger age groups exists predominantly between drivers aged 75 years and above and those aged 16 to 74. Therefore, it appears that drivers aged 75 and older are also the older drivers of particular interest when investigating the likelihood of the driver being seriously or fatally injured in a crash.

It was predicted that the rural older drivers who were involved in a crash would be more likely than urban older drivers to have been seriously or fatally injured. For this comparison, serious crash involvement of rural and urban drivers aged 75 and over was compared. Consistent with the prediction, the percentage of rural drivers aged 75 and over who were seriously or fatally injured (8.4%, 99%CI = 6.3-10.5) was more than double that of urban drivers aged 75 and over (3.4%, 99%CI = 2.7-4.1), as demonstrated in Figure 6. Figure 6 also shows that the percentages of seriously or fatally injured drivers aged 16 to 74 in both rural (5.8%, 99%CI = 5.4-6.2) and urban (1.8%, 99%CI = 1.7-1.9) areas were significantly lower than the corresponding percentages for drivers aged 75 and over. As there is no overlap in any of the confidence intervals, this indicates that living rurally and being aged 75 and over

both lead to a significantly greater likelihood of serious or fatal injury for crash-involved drivers. The effect of location, however, is stronger than age.

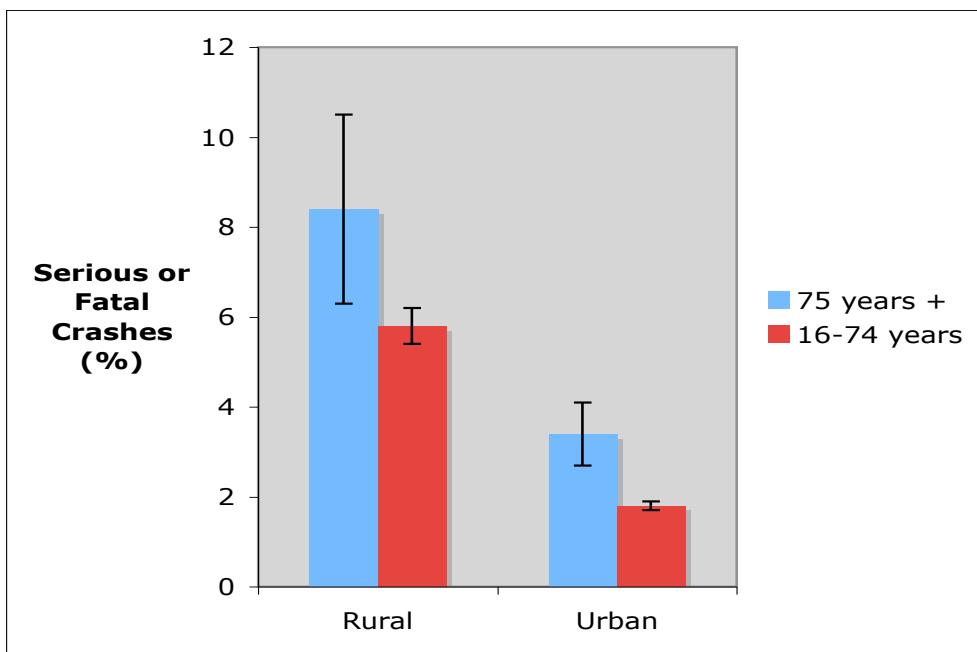


Figure 6. Comparison of the proportions of seriously or fatally injured rural and urban drivers by age (75 and over; 16 to 74 years) for the years 2004 to 2008, South Australia.

Note. Confidence intervals are illustrated by the black lines.

Discussion

The results of this investigation replicate some of the findings of previous research into the crash involvement of older drivers. Consistent with past research (Baldock, 2004; Ryan, et al., 1998), it was found that older drivers have fewer crashes than all other age groups and that this is still the case when differences between age groups in population numbers and amount of licensure are taken into account. These previous findings were extended by demonstrating that these trends in crash involvement were evident in both rural and urban drivers. Also, corresponding with previous research (Baldock, 2004; Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meuleners, et al., 2006; Ryan, et al., 1998), older drivers had a greater likelihood than other age groups of being involved in crashes that

resulted in a serious injury or fatality and where they were themselves seriously or fatally injured. Again, this study additionally assessed this for both rural and urban drivers.

Furthermore, serious and fatal injury crash rates for rural and urban drivers aged 75 years and older were compared and it was found that rural drivers of that age have more than twice the likelihood of being involved in such crashes than their urban counterparts. When the serious injury and fatality rates of rural and urban drivers aged 75 and older were compared to rural and urban drivers aged 16 to 74, the drivers aged 75 and older for both areas had a significantly greater likelihood of being involved in these crashes. Therefore, a greater likelihood of serious injury and fatality is related to the driver living rurally and being in the 75 and older age range. Thus, this study indicates that the age range of particular interest when looking at serious or fatal injury crashes is 75 years and above, rather than the traditional conception of older drivers being those aged 65 years and older. This would fit with notions that people are living longer and healthier lives, and that their health and abilities do not decline until later in life compared with previous cohorts.

It was hoped that crash rates on a per kilometre driven basis could have been assessed. However, due to the inadequacy and paucity of the available distance travelled exposure data this assessment was not possible. In particular, exposure data that would allow a comparison of rural and urban older drivers was not available. Consequently, future research should attempt to gain reliable and objective exposure data that could be used for such analyses. Research (Baldock & McLean, 2005), however, has indicated that, especially from the perspective of the re-licensing of older drivers, the important crash rate to consider is that of crashes per licensed driver, and this was undertaken in the current study.

Another limitation of the study relates to the possibility that the police-reported crash data are affected by the under-reporting of crashes. This is likely to be a greater problem for crashes of low severity. If the likelihood of low severity crashes being reported differs by the age of the driver or the location of the crash (urban versus rural), then this will affect the

pattern of results. Previous research has indeed found a greater degree of under-reporting of lower severity crashes in rural or remote locations (Aptel et al., 1999; Langford, 2004). Whilst such under-reporting could lead to an over-estimate of the increased likelihood of a severe injury in a rural crash, it is unlikely to be the sole reason for the patterns of crash injury severity identified in this study.

The overall conclusion of this investigation is that older drivers who live rurally present the highest risk of serious injury and fatality from the crashes in which they are involved, when compared to all other driver groups defined in terms of age and residential locality. When investigating the safety of older drivers in general, this study provides clear evidence that rural older drivers comprise a subgroup that deserves significant attention from road safety research.

With regard to future research, it would be particularly beneficial to examine the potential underlying causes of the greater likelihood of serious or fatal injury crashes for rural older drivers. The age effect may be due to increased fragility or declining abilities, while the location effect may be related simply to the higher speed limits on rural roads. However, given the need for the ongoing mobility of older adults (Adler, et al., 1999; Marottoli, et al., 2000; Marottoli, Mendes de Leon, et al., 1997), and the likely greater needs for driving in rural areas due to the lack of availability of other options (Corcoran, et al., 2005; Johnson, 1995), there is often a compelling need for older drivers in rural areas to continue driving. For this reason, it is important to take a closer look at the nature of crashes involving rural older drivers, and the nature of their mobility needs, to determine if there are changes that can be made to driving patterns or behaviours to mitigate the risk of severe injury crashes, while enabling continued mobility. Furthermore, such an analysis could identify changes that could be made by road and transport authorities to help older adults in rural areas safely meet their mobility needs.

References

- Adler, G., Rottunda, S., & Kuskowski, M. (1999). Dementia and driving: Perceptions and changing habits. *Clinical Gerontologist, 20*(2), 23-35. doi: 10.1300/J018v20n02_03
- Aptel, I., Salmi, L. R., Masson, F., Bourdé, A., Henrion, G., & Erny, P. (1999). Road accident statistics: Discrepancies between police and hospital data in a French island. *Accident Analysis and Prevention, 31*(1-2), 101-108. doi: 10.1016/S0001-4575(98)00051-7
- Baldock, M. R. J. (2004). *Self-Regulation of the Driving Behaviour of Older Drivers*. PhD, PhD Thesis, University of Adelaide, Adelaide, Australia. Retrieved from
<http://digital.library.adelaide.edu.au/dspace/handle/2440/37930>
- Baldock, M. R. J., & McLean, A. J. (2005). *Older drivers: Crash involvement rates and causes* (Report No. CASR015). Adelaide: Centre for Automotive Safety Research. Retrieved from
<http://digital.library.adelaide.edu.au/dspace/bitstream/2440/36418/1/CASR015.pdf>
- Borgialli, D. A., Hill, E. M., Maio, R. F., Compton, C. P., & Gregor, M. A. (2000). Effects of alcohol on the geographic variation of driver fatalities in motor vehicle crashes. *Academic Emergency Medicine, 7*(1), 7-13. doi: 10.1111/j.1553-2712.2000.tb01882.x
- Brown, L. H., Khanna, A., & Hunt, R. C. (2000). Rural vs urban motor vehicle crash death rates: 20 years of FARS data. *Prehospital Emergency Care, 4*(1), 7-13. doi: 10.1080/10903120090941551
- Corcoran, S., James, E. L., & Ellis, J. M. (2005). Do elderly Victorians in rural areas have access to public transport? *Road & Transport Research, 14*(1), 38-43. Retrieved from
<http://www.arrb.com.au/Information-services/Publications/Issue.aspx?id=39>
- Donaldson, A. E., Cook, L. J., Hutchings, C. B., & Dean, J. M. (2006). Crossing county lines: The impact of crash location and driver's residence on motor vehicle crash fatality. *Accident Analysis and Prevention, 38*(4), 723-727. doi: 10.1016/j.aap.2006.01.002

Gonzalez, R. P., Cummings, G. R., Phelan, H. A., Harlin, S., Mulekar, M., & Rodning, C. B.

(2007). Increased rural vehicular mortality rates: Roadways with higher speed limits or excessive vehicular speed? *The Journal of Trauma*, 63(6), 1360-1363. doi: 10.1097/TA.0b013e31815b83b3

Hanrahan, R. B., Layde, P. M., Zhu, S., Guse, C. E., & Hargarten, S. W. (2009). The association of driver age with traffic injury severity in Wisconsin. *Traffic Injury Prevention*, 10(4), 361-367. doi: 10.1080/15389580902973635

Johnson, J. E. (1995). Rural elders and the decision to stop driving. *Journal of Community Health Nursing*, 12(3), 131-138. doi: 10.1207/s15327655jchn1203_1

Langford, J. (2004). *Why we continue to under-count the road toll*. Sydney: Austroads.

Retrieved from <http://www.docstoc.com/docs/31868412/WHY-WE-CONTINUE-TO-UNDER-COUNT-THE-ROAD-TOLL-1-A-BRIEF-STATEMENT>

Langford, J., & Koppel, S. (2006). The case for and against mandatory age-based assessment of older drivers. *Transportation Research Part F*, 9(5), 353-362. doi: 10.1016/j.trf.2006.06.009

Li, G., Braver, E. R., & Chen, L. H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis and Prevention*, 35(2), 227-235. doi: 10.1016/S0001-4575(01)00107-5

Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor vehicle crash mortality: The role of crash severity and medical resources. *Accident Analysis and Prevention*, 24(6), 631-642. doi: 10.1016/0001-4575(92)90015-B

Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., & Berkman, L. F. (2000). Consequences of driving cessation: Decreased out-of-home activity levels. *Journal of Gerontology: Social Sciences*, 55B(6), S334-S340. doi: 10.1093/geronb/55.6.S334

- Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive symptoms: Prospective evidence from the New Haven Established Populations for Epidemiological Studies of the Elderly. *Journal of the American Geriatrics Society*, 45(2), 202-206. Retrieved from <http://psycnet.apa.org/psycinfo/1997-07396-004>
- Meulenens, L. B., Harding, A., Lee, A. H., & Legge, M. (2006). Fragility and crash over-representation among older drivers in Western Australia. *Accident Analysis and Prevention*, 38(5), 1006-1010. doi: 10.1016/j.aap.2006.04.005
- Muelleman, R. L., & Mueller, K. (1996). Fatal motor vehicle crashes: Variations of crash characteristics within rural regions of different population densities. *Journal of Trauma-Injury Infection and Critical Care*, 41(2), 315-320. Retrieved from http://journals.lww.com/jtrauma/Abstract/1996/08000/Fatal_Motor_Vehicle_Crashes__Variations_of_Crash.20.aspx
- Muelleman, R. L., Wadman, M. C., Tran, T. P., Ullrich, F., & Anderson, J. R. (2007). Rural motor vehicle crash risk of death is higher after controlling for injury severity. *Journal of Trauma-Injury Infection and Critical Care*, 62(1), 221-226. doi: 10.1097/01.ta.0000231696.65548.06
- Ryan, G. A., Legge, M., & Rosman, D. (1998). Age related changes in driver's crash risk and crash type. *Accident Analysis and Prevention*, 30(3), 379-387. doi: 10.1016/S0001-4575(97)00098-5

Chapter 4: Study 2

An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers.

This chapter consists of a published paper, but copyright restrictions prevent the reproduction of this paper in its published form. The details of this publication are:

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013). An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers. *Accident Analysis and Prevention*, 50, 768-775.
doi: 10.1016/j.aap.2012.06.028

The author of this thesis (James Thompson) gave a 15-minute presentation based on this study at the 2011 Emerging Issues in Safe and Sustainable Mobility for Older People conference held in Washington DC, USA.

Preamble

The preceding study provided evidence that, in South Australia, rural drivers who are aged 75 years and older have the highest likelihood of serious or fatal injuries following a crash compared to all other age groups and to urban residents. Indeed, they are more than twice as likely as urban drivers of the same age to be seriously or fatally injured when involved in a crash. It also highlighted the fact that it would be beneficial to examine the potential underlying causes of the increased likelihood of serious or fatal injury crashes for rural older drivers compared to older urban drivers so that this risk could potentially be addressed.

The purpose of the following study was to undertake such an investigation. The five years (2004 to 2008) of crash, serious injury, and fatality data that were used in the preceding study were analysed for this purpose. The database of police-reported road crashes in South Australia, the Traffic Accident Reporting System, that was used to obtain the preceding data also provided specific details relating to the crashes, such as the nature, police-attributed cause, time and location of the crash. This allowed for a detailed examination of the environmental, driver and vehicle factors that were involved in the crashes of rural and urban older drivers, as well as the association of these factors with serious or fatal injury. It was predicted that those factors that were more likely to be present in the crashes of older rural drivers (e.g. roads with a speed limit of 100km/h or higher) would increase the chances that a driver of any age would be seriously or fatally injured.

Additionally, the preceding study found that drivers aged 75 years and older (both rural and urban) were significantly more likely to be seriously or fatally injured when involved in a crash than drivers below this age. Therefore, although drivers aged 65 years and older have conventionally been categorised as “older drivers” (Kostyniuk & Shope, 2003), it appears that, those aged 75 and older may be the older drivers of particular interest when

examining the likelihood of serious or fatal injuries resulting from a crash. Consequently, the following study, as well as the remainder of the research contained in this thesis, used the age range of 75 and older to define older drivers.

**An examination of the environmental, driver and vehicle factors associated with the
serious and fatal crashes of older rural drivers.**

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The authors would like to express their gratitude to Jamie Mackenzie from the Centre for
Automotive Safety Research for extracting the TARS data.

Abstract

Motor vehicle crashes involving rural drivers aged 75 years and over are more than twice as likely to result in a serious or fatal injury as those involving their urban counterparts. The current study examined some of the reasons for this, using a database of police-reported crashes (2004 - 2008) to identify the environmental (lighting, road and weather conditions, road layout, road surface, speed limit), driver (driver error, crash type), and vehicle (vehicle age) factors that are associated with the crashes of older rural drivers. It also determined whether these same factors are associated with an increased likelihood of serious or fatal injury in younger drivers for whom fragility does not contribute to the resulting injury severity. A number of environmental (i.e. undivided, unsealed, curved and inclined roads, and areas with a speed limit of 100km/h or greater) and driver (i.e. collision with a fixed object and rolling over) factors were more frequent in the crashes of older rural drivers and additionally associated with increased injury severity in younger drivers. Moreover, when these environmental factors were entered into a logistic regression model to predict whether older drivers who were involved in crashes did or did not sustain a serious or fatal injury, it was found that each factor independently increased the likelihood of a serious or fatal injury. Changes, such as the provision of divided and sealed roads, greater protection from fixed roadside objects, and reduced speed limits, appear to be indicated in order to improve the safety of the rural driving environment for drivers of all ages. Additionally, older rural drivers should be encouraged to reduce their exposure to these risky circumstances.

Keywords: older drivers, rural areas, urban areas, fatality, serious injury, crash factors

Older drivers (i.e. 65 years and older) are involved in fewer motor vehicle crashes than other age groups, but have an increased risk of death and serious injury when they are involved in an accident (Baldock, 2004; Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meuleners, et al., 2006; Ryan, et al., 1998; Thompson, Baldock, Mathias, & Wundersitz, 2010). This increased risk of injury is believed to be caused by greater fragility, such that older people have a lowered tolerance to physical trauma and sustain more severe injuries than younger persons in comparable crashes (Li, et al., 2003; Viano, et al., 1990).

Regardless of age, drivers who live in rural areas are at a higher risk of serious or fatal injuries following a crash than drivers who reside in urban areas, despite the lower crash rates in rural areas (Borgialli, et al., 2000; Brown, et al., 2000; Donaldson, et al., 2006; Maio, et al., 1992; Muelleman, et al., 2007; Thompson, et al., 2010). Thompson et al. (2010) examined the crash rates, as well as the serious and fatal injuries, of drivers from rural and urban areas of South Australia across a range of ages. This study found that rural drivers who were aged 75 years and older had the lowest number of crashes when they were compared to all other age groups and to urban residents, but the highest likelihood of serious or fatal injuries following a crash. Indeed, they were more than twice as likely to be involved in crashes that resulted in a serious or fatal injury than urban drivers of the same age. This rural-urban differential has been attributed to a range of factors, including higher speed limits (Gonzalez, et al., 2007), delays in the delivery of medical care after a road accident (Muelleman & Mueller, 1996), the reduced availability of trauma medical care (Muelleman, et al., 2007), and greater alcohol usage (Borgialli, et al., 2000) in rural areas.

According to the South Australian Department of Planning, Transport and Infrastructure licensing figures for 2009, 28% of licensed older drivers (aged 75 years and over in South Australia) reside in rural areas. Thus, it is important to understand why older rural drivers have a higher likelihood of serious or fatal injuries in a crash than those who live in urban areas. Their increased likelihood of serious or fatal injury may be explained by the

tendency to be travelling at higher speeds when they crash (due to higher speed limits) or the issues relating to medical care discussed above. However, the intention of the present study was to determine whether there are other factors involved that have not previously been identified and which, along with speed limits, could be adjusted to make rural driving environments safer for older drivers. To determine what these other factors may be, the first aim was to identify any environmental (time of day/light, road and weather conditions, road layout, type of road surface, horizontal and vertical road alignment, speed limit), driver (type of driver error, crash type) and vehicle (vehicle age) factors that are more frequently involved in the crashes of older rural drivers than their urban counterparts. The second aim was to determine whether those factors that are more commonly associated with the crashes of older rural drivers are also associated with a greater likelihood of serious or fatal injuries for crashes in general. This was done by examining injury severity in younger drivers (16-74 years) for whom fragility does not contribute as much to injury severity levels.

It is possible that the higher speed limits found in rural areas (resulting in higher traveling speeds) may be the predominant reason why there is an increased likelihood of older rural drivers being seriously or fatally injured following a crash and, in addition, speed may mediate the effects of other environmental factors (e.g. the consequences of crashing on an unsealed road will differ depending on whether the car is travelling at a low or high speed). In addition to the mediating effect of speed, there may also be other interactions among the environmental factors, such that one may mediate the effects of another. For example, an unsealed road is also likely to be undivided, which may play a role in the higher injury severity in crashes on these roads. Consequently, the final aim of this study was to determine whether those factors that were more common in the crashes of older rural drivers also made independent contributions to the likelihood of serious or fatal injuries for older drivers. To do this, each of the factors that were more common for older rural drivers was entered into a logistic regression model to predict injury severity for older drivers.

Method

Materials

Crash data for the years 2004 to 2008, inclusive, were acquired through the Traffic Accident Reporting System (TARS), which is a database of all police-reported road crashes in South Australia that is managed by the Department of Planning, Transport and Infrastructure (DPTI). For a crash to be included in the database, at least one of the persons involved (e.g. the driver, other vehicle occupants, pedestrians, etc.) must have been injured, \$3000 or more worth of damage must have been caused to the vehicle(s), and/or one of the vehicles must have been towed away. If any of these criteria are met, then a driver is legally obliged to report the crash to the police. The TARS database records information relating to: the nature, cause, time and location of a crash; details of all drivers and any injured occupants or pedestrians who were involved in the crash; and the severity of any resulting injuries. It is a particularly useful database because, in addition to crashes in which people are injured, it records crashes where there is only property damage; therefore providing a comprehensive picture of the overall crash involvement of older rural drivers.

Measures

The data that were extracted from the TARS database and used in the analyses only included crashes where the driver involved was driving a car or comparable light passenger vehicle (e.g. utility, van, station wagon) because the circumstances of crashes involving other vehicles (e.g. taxis, trucks, motorcycles, etc.) may be fundamentally different. Background information on the driver and specific details of the crash were obtained. The background information on the driver included their *age* (in years) and *residential postcode* (4 digit code), with the latter being used to determine whether the driver lived in a rural or urban area of

South Australia and to group into “rural” or “urban” drivers for the purposes of statistical analyses⁶. Crashes in which the driver lived interstate or their postcode was not recorded were excluded for present purposes.

The details of the crash that were extracted included the postcode of the crash location, the severity of the driver injury and the year when the crash occurred, as well as the environmental, driver and vehicle factors involved. The *postcode* of the crash location was used to determine whether it occurred in a rural or urban area of South Australia. *Driver injury severity* refers to the degree of injury incurred by the driver involved in the crash and was recorded as one of five levels of severity: 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. For the purposes of this research, a serious injury was defined as one requiring admission to a hospital.

The information relating to the environmental factors that was obtained included the level of ambient light, road and weather conditions, road layout, road surface, horizontal and vertical road alignment, and speed limit at the crash location. The *levels of ambient lighting* were recorded on the TARS database as being daylight, dawn/dusk, or night. The *road conditions* were recorded as wet or dry, while the *weather conditions* were recorded as raining or not. The *road layout* where the crash occurred was classified as one of 15 types in the TARS database, such as a cross-road or freeway (for a full list see Table 3 in the Results section), and the *road surface* was classified as sealed, unsealed or unknown. The *horizontal road alignment* at the crash location was classified as straight road, curved road with view open, curved road with view obscured, or unknown. The *vertical road alignment* was categorised as being level, on a slope, at the crest of a hill, at the bottom of a hill, or unknown. *Speed limit at the crash location*, was recorded in terms of kilometres per hour.

⁶ This was based on a classification of South Australia postcodes, used by Kloeden (2008), whereby urban areas were defined as the capital city, Adelaide, and regions within a 5 to 20 kilometre radius of the central business district. Rural areas were defined as those regions outside of the urban area.

The information relating to the driver factors that was obtained included the type of driver error and the type of crash. *Driver error* was classified by the TARS database into 29 possible types, such as inattention or no error (for a full list see Table 5 in the Results section). Each driver that was involved in a crash was assigned one of these error-types by the investigating police officer. It is worth noting that some of the “errors” listed in the TARS database may reflect intentional driver choices rather than “errors” (e.g. excessive speed); however the term “error” was retained in order to remain consistent with the terminology used in the database. *Crash type* was classified as one of 13 possible categories in the TARS database, such as side-swipe or head-on crash (for a full list see Table 5 in the Results section). Also, the vehicle information that was obtained was the year of vehicle manufacture. This was subtracted from the year of the crash occurrence in order to calculate the *age of the vehicle* (in years) at the time of the crash.

In order to analyse the crash data in terms of the age group of drivers involved in the crashes, it was necessary to base the analysis on crash-involved drivers rather than crashes. One of the consequences of using these data is that, for crashes involving multiple drivers, each driver had a separate entry in the database. Thus, a single crash that involved two drivers counted as two crashes. For analyses focusing only on drivers aged ≥ 75 , crashes would only be counted twice in the rare cases (2.3%) when both drivers were in this age group.

Procedure and statistical analyses

A researcher trained in the use of the TARS database extracted the data that was required for the present study. As the data were de-identified, ethics approval was not required.

The statistical analyses were completed in four stages. First, summary statistics detailing the frequency and location (rural or urban) of crashes involving older drivers (≥ 75 years) were produced. Second, the frequency with which each of the environmental (lighting,

road and weather conditions, road layout, road surface, horizontal and vertical road alignment and speed limit at the crash location), driver (driver error, crash type) and vehicle (vehicle age) factors were involved in the crashes of rural and urban older drivers was examined. This was undertaken in order to determine which factors differed in frequency between the crashes of rural and urban older drivers. Third, for those variables that differed between these groups, we examined whether they were also related to crashes causing serious or fatal injuries in younger rural and urban drivers (aged 16 to 74) in order to determine whether these variables were associated with serious crashes, independent of where the driver lived and the effects of old age (i.e. the effect of fragility). Finally, each of the factors that were more common in the crashes of older rural drivers *and* more frequently associated with severe injuries in a younger sample (< 75 years) were examined using logistic regression to determine whether they made independent contributions to the likelihood of serious injury (serious/fatal injury versus all other levels of severity) in older drivers (≥ 75 years).

Results

Crash frequency and location

The total sample for which crash data were available from the TARS database was very large ($N = 149,621$). Consequently, the customary technique of using chi-square to compare frequency data was likely to yield statistically significant differences that were not necessarily of practical significance (i.e. an important road safety issue). Thus, percentages and 99% confidence intervals (99% CIs) were compared, with an absence of overlap in the confidence intervals indicating statistical significance. A conservative alpha level of .01 was used for the confidence intervals in order to guard against the increased likelihood of Type I errors resulting from multiple comparisons.

There were a total of 5,732 South Australian drivers of passenger vehicles who were aged \geq 75 years and who were involved in crashes that were reported to the South Australian police and recorded in the TARS database between 2004 and 2008. These drivers were involved in a total of 5,605 crashes, 127 (2.3%) of which involved two older drivers (aged \geq 75; none involved three or more drivers) and were, therefore, counted twice in the data. Of the 5,732 older drivers involved in crashes, 1,151 (20.1%) were from rural areas of South Australia and 4,581 (79.9%) were from urban areas. The latter two figures ($N = 1,151$ and 4,581) were used when calculating the percentages of total crashes for rural and urban older drivers.

The locations at which the crashes occurred were divided into rural and urban areas, based on the postcode of the crash site, and tabulated separately for rural and urban drivers, based on the drivers' postcodes. As can be seen from Table 1, older rural drivers were, not surprisingly, significantly more likely to crash in rural areas and older urban drivers in urban areas. This means that the environmental factors associated with the crashes of these two groups of drivers are likely to reflect differences between rural and urban environments. For example, it would be expected that older urban drivers, compared with older rural drivers, would have a greater proportion of their crashes on straight rather than curved roads, as urban areas have a higher proportion of straight roads.

Table 1

Percentage of Total Crashes by Location of the Crash (Rural or Urban) and Residential Location (Rural or Urban) of the Driver (Aged \geq 75 years) between 2004 and 2008, South Australia

		Residential Location of the Drivers			
		Percentage - Rural drivers	99% CIs - Rural drivers	Percentage - Urban drivers	99% CIs - Urban drivers
Crash Location	Rural	82.2	79.3 – 85.1	4.1	3.3 – 4.9
	Urban	17.8	14.9 – 20.7	95.9	95.1 – 96.7
Total		100.0		100.0	

Note. Rows in bold indicate statistical significance (i.e. no overlap in the confidence intervals).

Rural vs urban crashes involving older drivers: Frequency of environmental, driver and vehicle factors

The crashes of rural and urban older drivers (≥ 75 years) were examined in terms of the frequency of the environmental, driver and vehicle factors that were involved in order to determine which factors were more likely to characterize the crashes of each group.

Environmental factors: As seen in Table 2, there were no statistically significant differences between rural and urban older drivers regarding the level of *lighting*, or in the *road conditions* or *weather conditions* when the crash occurred.

Table 2

Percentage of Total Crashes by Lighting/Road Conditions/Weather Conditions and Residential Location (Rural or Urban) of the Driver (Aged 75 and Over) for the Years 2004 to 2008, South Australia

	Percentage - Rural	99% CIs - Rural	Percentage - Urban	99% CIs - Urban
Lighting				
Daylight	92.5	90.5 – 94.5	91.0	89.9 – 92.1
Dawn/Dusk	0.2	-0.1 – 0.5	0.1	0.0 – 0.2
Night	7.3	5.3 – 9.3	9.0	7.9 – 10.1
Total	100.0		100.0	
Road Conditions				
Wet	10.6	8.3 – 12.9	8.8	7.7 – 9.9
Dry	89.3	87.0 – 91.6	91.2	90.1 – 92.3
Total	100.0		100.0	
Weather Conditions				
Raining	8.3	6.2 – 10.4	5.9	5.0 – 6.8
Not raining	91.7	89.6 – 93.8	94.1	93.2 – 95.0
Total	100.0		100.0	

Note. There were no statistically significant differences for any of the factors in this table.

In terms of *road layout*, Table 3 shows that older rural drivers were significantly more likely to crash on undivided roads (i.e. where there was no dividing barrier between lanes of opposite direction), while older urban drivers were more likely to crash on divided roads. For *road surface*, older rural drivers were more likely to crash on unsealed roads, while older urban drivers were more likely to crash on sealed roads. For *horizontal road alignment*, older rural drivers were more likely to crash on curved roads with both open and obscured views,

while older urban drivers were more likely to crash on straight roads. For *vertical road alignment*, older rural drivers were more likely to crash on a slope and on the crest of a hill, while older urban drivers were more likely to crash on a level road.

Table 3

Percentage of Total Crashes by Road Layout/Road Surface/Horizontal Road Alignment/Vertical Road Alignment and Residential Location (Rural or Urban) of the Driver (Aged 75 and Over) for the Years 2004 to 2008, South Australia

	Percentage - Rural	99% CIs - Rural	Percentage - Urban	99% CIs - Urban
Road Layout				
Undivided road	33.4	29.8 – 37.0	16.7	15.3 – 18.1
Cross road	28.6	25.2 – 32.0	27.5	25.8 – 29.2
T-junction	25.4	22.1 – 28.7	28.5	26.8 – 30.2
Divided road	6.3	4.5 – 8.1	18.3	16.8 – 19.8
Multiple	1.4	0.5 – 2.3	1.6	1.1 – 2.1
Freeway	0.8	0.1 – 1.5	0.2	0.0 – 0.4
Rail crossing	0.3	0.1 – 0.5	0.4	0.2 – 0.6
Pedestrian crossing	0.2	-0.1 – 0.5	0.3	0.1 – 0.5
Y-junction	0.2	-0.1 – 0.5	0.1	0.0 – 0.2
Crossover	0.1	-0.1 – 0.3	0.2	0.0 – 0.4
Interchange	0.0	N/A	0.1	0.0 – 0.2
One way	0.0	N/A	< 0.1	N/A
Ramp on	0.0	N/A	< 0.1	N/A
Other	3.6	2.2 – 5.0	6.1	5.2 – 7.0
Total	100.0		100.0	
Road Surface				
Sealed	95.9	94.4 – 97.4	99.4	99.1 – 99.7
Unsealed	4.1	2.6 – 5.6	0.5	0.2 – 0.8
Unknown	0.0	N/A	< 0.1	N/A
Total	100.0		100.0	
Horizontal Road Alignment				
Straight road	88.0	85.5 – 90.5	94.6	93.7 – 95.5
Curved - view open	8.7	6.6 – 10.8	4.2	3.4 – 5.0
Curved - view obscured	3.1	1.8 – 4.4	1.0	0.6 – 1.4
Unknown	0.2	-0.1 – 0.5	0.2	0.0 – 0.4
Total	100.0		100.0	
Vertical Road Alignment				
Level	84.1	81.3 – 86.9	90.7	89.6 – 91.8
Slope	10.8	8.4 – 13.2	7.0	6.0 – 8.0
Crest of hill	3.3	1.9 – 4.7	1.2	0.8 – 1.6
Bottom of hill	1.6	0.6 – 2.6	0.8	0.5 – 1.1
Unknown	0.3	-0.1 – 0.7	0.3	0.1 – 0.5
Total	100.0		100.0	

Note. N/A = not applicable (because confidence intervals cannot be calculated for 0.0 or < 0.1%).

Note. Rows in bold indicate statistical significance (i.e. no overlap in the confidence intervals).

Note. One type of road layout was omitted from the table because no crashes occurring on such a section of road were recorded for rural or urban older drivers between 2004 to 2008.

Many different *speed limits* were recorded in the TARS database, some of which were spurious (e.g. 0 and 1 km/h, speed limit not recorded, etc.). Consequently, only those that are common speed limits on South Australian roads were examined (i.e. 10, 40, 50, 60, 70, 80, 90, 100, 110 km/h). Table 4 indicates that older rural drivers were more likely to crash in locations with speed limits of 50, 80, 100 and 110 km/h, while older urban driver crashes were more likely in 40 and 60 km/h zones.

Table 4

Percentage of Total Crashes by Speed Limit and Residential Location (Rural or Urban) of the Driver (Aged 75 and Over) for the Years 2004 to 2008, South Australia

Speed Limit at Crash Location (km/h)	Percentage - Rural	99% CIs - Rural	Percentage - Urban	99% CIs - Urban
10	1.1	0.3 – 1.9	2.3	1.7 – 2.9
40	0.2	-0.1 – 0.5	1.5	1.0 – 2.0
50	38.3	34.6 – 42.0	25.0	23.3 – 26.7
60	29.4	25.9 – 32.9	59.9	58.0 – 61.8
70	1.5	0.6 – 2.4	3.0	2.3 – 3.7
80	8.8	6.6 – 11.0	4.6	3.8 – 5.4
90	0.9	0.2 – 1.6	0.4	0.2 – 0.6
100	9.4	7.2 – 11.6	1.8	1.3 – 2.3
110	10.3	8.0 – 12.6	1.4	0.9 – 1.9
Total	100.0		100.0	

Note. Rows in bold indicate statistical significance (i.e. no overlap in the confidence intervals).

Driver factors: For the *driver error* that was attributed to the cause of the crash, older rural drivers were more likely to disobey a give-way sign and fail to give way to the right in a crash (refer to Table 5 for the results and a full list of the 29 types of driver error). Older urban drivers were more likely to disobey traffic lights, consistent with the fact that urban areas have more signalised intersections. They were also more likely to be involved in a crash for which they were not assigned a driver error. For the *type of crash*, older rural drivers were more likely to hit another vehicle at a right-angle, hit a fixed object, and experience a vehicle roll-over, while older urban drivers were more likely to be involved in rear-end and right turn crashes (see Table 5 for the results and a full list of the 13 crash types).

Table 5
Percentage of Total Crashes by Driver Error/Crash Type and Residential Location (Rural or Urban) of the Driver (Aged 75 and Over) for the Years 2004 to 2008, South Australia

	Percentage - Rural	99% CIs - Rural	Percentage - Urban	99% CIs - Urban
Driver Error				
Inattention	19.5	16.5 – 22.5	21.7	20.1 – 23.3
Fail to give way	17.8	14.9 – 20.7	15.4	14.0 – 16.8
Disobey give way sign	9.2	7.0 – 11.4	3.9	3.2 – 4.6
Fail to stand ^a	6.6	4.7 – 8.5	8.0	7.0 – 9.0
Reverse without due care	5.5	3.8 – 7.2	4.5	3.7 – 5.3
Disobey stop sign	4.5	2.9 – 6.1	3.1	2.4 – 3.8
Follow too closely	2.3	1.2 – 3.4	1.9	1.4 – 2.4
Fail to give way to the right^b	2.1	1.0 – 3.2	0.7	0.4 – 1.0
Change lanes to endanger ^c	1.7	0.7 – 2.7	3.1	2.4 – 3.8
Died, sick ,or asleep at wheel	1.4	0.5 – 2.3	0.5	0.2 – 0.8
Misjudgment	1.1	0.3 – 1.9	0.6	0.3 – 0.9
Overtake without due care	1.0	0.2 – 1.8	0.6	0.3 – 0.9
Fail to keep left	0.9	0.2 – 1.6	0.9	0.5 – 1.3
Disobey traffic lights	0.8	0.1 – 1.5	3.0	2.4 – 3.6
Vehicle fault	0.6	0.0 – 1.2	0.2	0.0 – 0.4
Incorrect turn (e.g. illegal U-turn)	0.3	-0.1 – 0.7	0.5	0.2 – 0.8
Driving under influence of alcohol/drugs	0.3	-0.1 – 0.7	0.3	0.1 – 0.5
Opening or closing door	0.2	-0.1 – 0.5	0.1	0.0 – 0.2
Excessive speed	0.1	-0.1 – 0.3	< 0.1	N/A
Disobey railway signal	0.1	-0.1 – 0.3	0.0	N/A
Brake failure	0.0	N/A	< 0.1	N/A
No errors	23.9	20.7 – 27.1	30.9	29.1 – 32.7
Other	0.1	-0.1 – 0.3	< 0.1	N/A
Total	100.0		100.0	
Crash Type				
Right angle	40.6	36.9 – 44.3	32.3	30.5 – 34.1
Rear-end	14.9	12.2 – 17.6	25.0	23.4 – 26.6
Hit fixed object	13.5	10.9 – 16.1	8.3	7.3 – 9.3
Side swipe	10.7	8.4 – 13.0	10.0	8.9 – 11.1
Right turn	8.3	6.2 – 10.4	12.4	11.1 – 13.7
Hit parked vehicle	5.7	3.9 – 7.5	7.6	6.6 – 8.6
Rollover	2.1	1.0 – 3.2	0.4	0.2 – 0.6
Head on	1.6	0.6 – 2.6	1.9	1.4 – 2.4
Hit pedestrian	1.1	0.3 – 1.9	1.4	1.0 – 1.8
Hit animal	0.9	0.2 – 1.6	0.1	0.0 – 0.2
Left road - out of control	0.2	-0.1 – 0.5	0.2	0.0 – 0.4
Hit object on road	0.0	N/A	0.2	0.0 – 0.4
Other	0.6	0.0 – 1.2	0.3	0.1 – 0.5
Total	100.0		100.0	

Note. N/A = not applicable (because confidence intervals cannot be calculated for 0.0 or < 0.1%).

Note. Rows in bold indicate statistical significance (i.e. no overlap in the confidence intervals).

Note. Six types of driver error were omitted from the table because no crashes involving these errors were recorded for rural or urban older drivers between 2004 to 2008.

^aI.e. driver does not wait for an appropriate gap when turning right across oncoming traffic.

^bNote: cars drive on the left hand side of the road in Australia.

^cI.e. driver chooses an inappropriate time to change lanes on a multi-lane road.

Vehicle factors: The variable ‘*vehicle age*’ was examined using a non-parametric Mann–Whitney test because the data were non-normally distributed. There was no significant difference between the median age of vehicles driven by older urban drivers (median = 12 years) and older rural drivers (median = 11 years) ($U = 2.51, p = 0.578$ (two-tailed), $z = -0.557$) in their crashes. Thus, the age, and presumably safety, of their vehicles did not differ.

To summarise, the crashes of rural and urban older drivers differed in the layout, surface, and horizontal and vertical alignment of the road, as well as the speed limit, at the crash location. They also differed in the driver error involved and the type of crash. Older rural drivers were more likely to crash on undivided, unsealed, curved and inclined roads, and in areas with speed limits of 50, 80, 100 or 110km/h. They were also more likely to make errors in which they disobeyed a give-way sign or failed to give way to the right, and be involved in crashes in which they hit another vehicle at a right-angle, hit a fixed object, or experienced a vehicle roll-over. Older urban drivers were more likely to crash on divided, sealed, straight and level roads; crash in areas with speed limits of 40 and 60km/h; disobey traffic lights in a crash; and have rear end and right turn crashes.

Environmental and driver factors and their association with injury severity

The environmental and driver factors that differed in frequency between rural and urban older drivers (i.e. road layout, road surface, road alignment, speed limits, driver error, crash type) were then examined in terms of their association with a serious or fatal injury to the driver. Data for younger drivers (aged 16-74) from both rural and urban areas were examined to reduce the potentially confounding effects of old age (i.e. fragility) and driving region on injury severity. For each factor (e.g. undivided road), the proportion of crashes (and 99% CIs) where the factor was present and had serious or fatal consequences for younger drivers was examined. This analysis was designed to determine whether those factors that are

more common in the crashes of older rural drivers have a higher likelihood of causing serious or fatal injury compared to those that are more common for older urban drivers.

In terms of *road layout*, Table 6 shows that crashes on undivided roads, which were found to be more common for older rural drivers (see Section 3.2), had more than three times the likelihood of causing serious injuries to the driver than those on divided roads, which were found to be more frequent amongst older urban drivers. For *road surface*, crashes on unsealed roads, which were found to be more likely for older rural drivers, were more than four times more likely to cause a fatal or serious injury than crashes on sealed roads. For *road alignment*, crashes on curved roads (with both open and obscured views), which were more common for older rural drivers, had more than three times the likelihood of causing serious or fatal injuries than those on straight roads, which were more common for older urban drivers. Similarly, crashes on a slope or the crest of a hill, which were more likely for older rural drivers, were twice as likely to be serious or fatal than those on level roads, which were more common for older urban drivers.

Table 6

Environmental Factors of Serious or Fatal Crashes for Drivers Aged 16 to 74 in South Australia for the Years 2004 to 2008: Descriptive Statistics

	Serious or Fatal Crashes (%)	99% CIs
Road Layout		
Undivided road	5.7	5.4 - 6.0
Divided road	1.6	1.4 - 1.8
Road Surface		
Sealed	2.3	2.2 - 2.4
Unsealed	9.5	8.2 - 10.8
Horizontal Road Alignment		
Straight road	2.0	1.9 - 2.1
Curved - view open	6.9	6.2 - 7.6
Curved - view obscured	6.9	5.9 - 7.9
Vertical Road Alignment		
Level	2.2	2.1 - 2.3
Slope	4.4	3.9 - 4.9
Crest of hill	5.4	4.2 - 6.6

In terms of *speed limits*, it can be seen in Figure 1 that crashes in 100 and 110km/h areas had two to three times the likelihood of causing serious or fatal injuries compared to crashes in areas with the other speed limits. Both of these speeds were more likely to apply to roads where older rural drivers were more likely to crash.

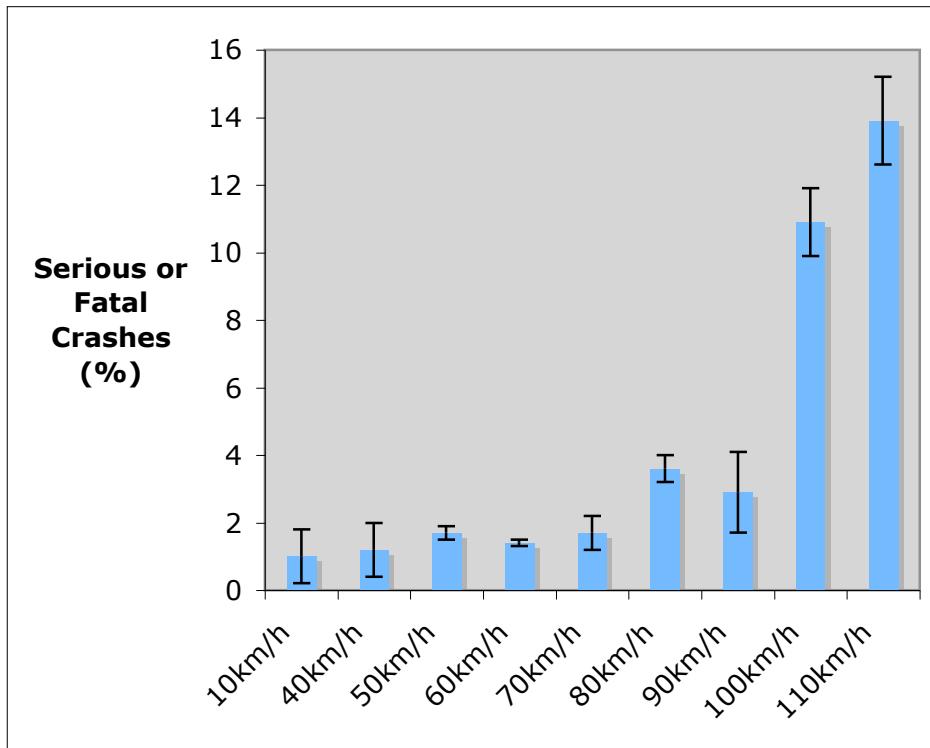


Figure 1. Percentage of drivers (aged 16 to 74) seriously injured or killed by crashes at locations with various speed limits for the years 2004 to 2008, South Australia.
Note. 99% Confidence intervals are illustrated by the black lines.

With respect to *driver error*, Table 7 shows that the three errors types of interest (disobeyed a give-way sign, failed to give-way to the right, disobeyed traffic lights) had similar proportions of serious or fatal crashes and overlapping confidence intervals. Thus, neither the errors that were more common in the crashes of older rural drivers (disobeying a give-way sign, failing to give-way to the right) nor older urban drivers (disobeying traffic lights) had a higher likelihood of resulting in crashes where the driver was seriously or fatally injured. For *crash type*, two (hitting fixed object, rollover) of the three crash types that older rural drivers were more likely to be involved in were more likely to cause serious or fatal

injuries. While more common in older rural drivers, right-angle crashes were not generally associated with serious injuries in younger drivers. Rear-end and right-turn crashes, which are more common for older urban drivers, also had a lower likelihood of causing serious injuries.

Table 7

Driver Factors of Serious or Fatal Crashes for Drivers Aged 16 to 74 in South Australia for the Years 2004 to 2008: Descriptive Statistics

	Serious or Fatal Crashes (%)	99% CIs
Driver Error		
Disobey give way sign	3.0	2.0 - 4.0
Fail to give way to the right	2.0	0.4 - 3.6
Disobey traffic lights	2.3	1.4 - 3.2
Crash Type		
Right angle	1.7	1.5 - 1.9
Rear-end	0.6	0.5 - 0.7
Hit fixed object	8.9	8.3 - 9.5
Right turn	1.9	1.6 - 2.2
Rollover	18.8	16.6 - 21.0

Overall, many of the environmental and driver factors that were more common in the crashes of older rural drivers also tended to be associated with serious or fatal injuries to younger drivers. This may help to explain why older rural drivers are more likely to be seriously or fatally injured than older urban drivers. These factors included crashing on undivided, unsealed, curved and inclined roads, and in areas with a speed limit of 100km/h or greater, as well as hitting a fixed object and rolling over. In contrast, the factors that were more common in the crashes of older urban drivers had low levels of involvement in serious or fatal crashes in younger drivers.

Prediction of serious/fatal injuries in older drivers, controlling for relationships between the environmental factors

The factors that were more common in the crashes of older rural drivers and had an increased association with serious or fatal injuries for younger drivers were then entered as independent variables in a logistic regression model examining the combined data for older

drivers from both rural and urban areas (refer to Table 8). Although hitting a fixed object and rolling over met these criteria for inclusion in the logistic regression model, they were left out because the overall purpose of this examination was to identify the environmental factors that increase the likelihood of serious injury. Consequently, the independent variables in the model were six environmental factors, which were treated as binary variables, namely: undivided road or not, unsealed road or not, curved road or not, on a slope or not, on a crest of a hill or not, speed limit at the crash location \leq 90km/h or \geq 100km/h. These variables were entered into the model in a forward stepwise method. The dependent variable was whether a crash did or did not result in a serious/fatal injury to the driver. This model allowed for an examination of the effects of each factor on older driver injury severity, independent of any relationship with the other explanatory variables in the model. An alpha level of 0.05 was used for this analysis.

Table 8
Results of Logistic Regression Analysis Designed to Predict Whether a Crash will Involve a Serious or Fatal Injury to the Driver (Aged 75 and Over) for the Years 2004 to 2008, South Australia

Variable	B	SE	Wald	p-value	Odds ratio	99% CI
Undivided road	0.48	0.15	9.78	0.002	1.61	1.09 – 2.39
Unsealed road	0.80	0.32	6.07	0.014	2.22	0.96 – 5.13
Curved road	0.54	0.20	7.10	0.008	1.71	1.02 – 2.86
Crest of hill	0.71	0.35	4.09	0.043	2.04	0.82 – 5.07
Over 100km/h	1.51	0.18	71.70	<0.001	4.52	2.86 – 7.15

Note. p-values in bold indicate statistical significance at the $p < .05$ level.

As seen in Table 8, one type of road layout (undivided, OR = 1.61), one type of road surface (unsealed, OR = 2.22), two types of road alignment (curved, OR = 1.71; crest of a hill, OR = 2.04) and a speed limit of 100km/h or greater (OR = 4.52) each made independent and statistically significant contributions to the probability that a crash would result in serious or fatal injuries to the older driver (from rural or urban areas). Speed limit was the strongest predictor in the model. In addition, the forward stepwise method did not allow one type of

road alignment (slope) to be entered into the model because it did not meet the alpha criterion of .05.

Discussion

This study was designed to improve our understanding of the differences in the crashes that rural and urban older drivers are involved in for the purpose of explaining why older rural drivers are more than twice as likely as their urban counterparts to be seriously or fatally injured in a crash (Thompson, et al., 2010). This was achieved by firstly identifying the environmental, driver and vehicle factors that are more common in the crashes of older rural drivers and examining whether these factors have an increased likelihood of resulting in serious or fatal injury to younger drivers for whom fragility does not contribute to the resulting injury severity.

It was found that crashes that occurred on undivided, unsealed, curved and inclined roads, and in areas with a speed limit of 100km/h or greater, as well as those that involved hitting a fixed object and rolling over are more frequent for older rural drivers and have an increased level of injury severity for younger drivers. Thus, these environmental and driver factors constitute at least part of the difference between the crashes of rural and urban older drivers that makes older rural drivers more likely to be seriously or fatally injured.

The effects of the environmental factors of interest on the likelihood of serious or fatal injury were also examined for older drivers using regression analysis. Crashing on undivided, unsealed and curved roads, as well as on a crest of a hill or in an area with a speed limit of 100km/h or greater all independently predicted whether a crash would be serious or fatal. A speed limit of 100km/h or greater was the strongest predictor in the model.

The finding that crashes on roads with speed limits of 100 and 110km/h are more common for older rural drivers and more likely to result in serious injury is not surprising and

is consistent with expectations. Higher speed limits occur more frequently in rural areas, resulting in higher speeds at the time of impact and greater injury severity. Gonzalez et al. (2007) investigated the influence of high speed limits on mortality rates for drivers of all ages and found that, when a vehicle is traveling in excess of the limit, the mortality rates for crashes are similar between rural and urban areas. However, when traveling within the speed limit, the mortality rates are higher in rural areas.

As is the case with the speed limit at the crash location, many of the factors that are more likely for both rural and urban older driver crashes reflect their respective driving environments. In rural areas, there are more undivided, unsealed, curved and inclined roads, all of which were associated with serious injuries. In urban areas, there are more traffic lights and intersections, which would result in more rear-end and right-turn crashes. Furthermore, there are more divided, sealed, straight and level roads in urban areas. These were all found to be associated with less serious injuries. Thus, the significant contribution of this study is that it highlights the specific elements of rural driving environments that put older drivers who live there at a greater risk of serious injury and, therefore, what environmental, infrastructural, regulatory, and self-regulatory changes may make it safer for these drivers.

Environmental and infrastructural changes could include dividing previously undivided rural roads with centre-of-the-road wire rope barriers (McTiernan, Thoresen, & McDonald, 2009) to reduce the number and severity of crashes on them. Improvements to the maintenance of roads or sealing the surface of unsealed rural roads would enhance their safety by providing superior grip on these surfaces (Boschert, Pyta, Turner, & Green, 2010). Moreover, sealing the shoulders of curved roads and providing better delineation may reduce the number of instances in which drivers lose control of their vehicles, and ensuring adequate sight distance around curves would reduce the number and severity of crashes (Baldock, Kloeden, et al., 2008). In addition, a reduction in the number of road junctions that are adjacent to curved roads and crests of hills would make these locations safer (Baldock,

Kloeden, et al., 2008). While it is recognized that it is not realistic to suggest that all undivided, unsealed and curved rural roads, as well as all the sections of rural roads located at the crest of a hill, be improved in these ways, prioritized improvements to roads would be expected to yield long term cost-effective benefits. Additionally, the need for greater protection of fixed roadside objects, such as trees and utility poles, on rural roads (especially curved rural roads) has previously been suggested by Baldock et al. (2008), with Doecke and Woolley (2010) indicating that roadside barriers are the most practical method of achieving this.

A reduction in speed limits would be a regulatory change that would decrease the likelihood and level of severity of rural crashes. Consistent with this, research by Long et al. (2006) has found that a reduction in the 110km/h speed limit to 100km/h on certain rural roads in South Australia in 2003 reduced both the average traveling speed and the number of crashes in which there were casualties at these sites. Reduced speed limits would also mitigate the impact of many of the other factors that were identified, in the current study, as increasing injury severity.

Importantly, these changes would be beneficial to the safety of drivers of all ages. Indeed, had the aims of the study been different, this research could have compared rural and urban drivers of all ages and, potentially, have identified similar factors as being more generally associated with the crashes of rural drivers and an increased likelihood of serious or fatal injuries. However, the changes recommended here are based on the factors that are particularly relevant to the safety of older drivers because they have such a high likelihood of serious or fatal injury (Thompson, et al., 2010).

Ideally, older rural drivers should also reduce their exposure to these environmental factors that are hazardous or, in other words, self-regulate their driving. However, this may be difficult given that they are likely to have a high level of dependency on driving due to a reduced availability of alternative mobility options, such as public transport (Corcoran, et al.,

2005), and friends and family (Johnson, 1995). Thus, they potentially face the added difficulty of not only having to deal with a more hazardous driving environment, compared to their urban counterparts, but also having a greater reliance on driving, resulting in greater driving exposure.

There were a number of limitations to this study, one of which relates to there being no information in the TARS database about traveling speed at the time of the crash. Consequently, speed limit at the crash location was effectively used as a proxy for traveling speed. However, it was important to examine speed limit because this study examined the road environments of rural and urban areas, and speed-limits are a fundamental component of road use and safety.

Another limitation relates to the potential for the police-reported crash data to under-report crashes, particularly those of low severity. If the likelihood of low-severity crashes being reported to police differs by the age of the driver or the location of the crash (urban versus rural), this may have affected the pattern of results. Greater under-reporting of low severity crashes in rural or remote locations has been previously confirmed (Aptel, et al., 1999; Langford, 2004). Whilst such under-reporting may result in an over-estimation of the likelihood of a severe injury resulting from a rural crash, it is unlikely to be the only basis for the patterns injury severity identified in this study.

Finally, there are other factors which could explain the higher injury severity of older rural driver crashes that were not explored in this study. For example, it was noted earlier that delays in the delivery of medical care in rural areas could lead to more severe injuries (Muelleman & Mueller, 1996; Muelleman, et al., 2007). Thus, the finding that more serious injuries are sustained on unsealed roads may be due to delays in medical care caused by the fact that such roads tend to have less traffic, leading to fewer witnesses who would otherwise contact emergency services. Unfortunately, daily traffic count data for each crash site was not available for analysis. Furthermore, unsealed roads in South Australia are often characterised

by the presence of unprotected roadside hazards, which are likely to play a role in the more serious injuries that are sustained in crashes on these roads (Boschert, et al., 2010).

Research is now needed to investigate the extent to which older rural and urban drivers are exposed to these hazardous situations. This could be achieved by collecting detailed exposure data on where older drivers regularly drive, the driving conditions in those locations, and the proportion of driving that occurs at locations that are associated with an increased likelihood of sustaining a severe injury in the event of a crash. This may help to identify how best to reduce the exposure of older rural drivers to hazardous situations, either through adjustments to the road environment or to driving patterns.

References

- Aptel, I., Salmi, L. R., Masson, F., Bourd  , A., Henrion, G., & Erny, P. (1999). Road accident statistics: Discrepancies between police and hospital data in a French island. *Accident Analysis and Prevention*, 31(1-2), 101-108. doi: 10.1016/S0001-4575(98)00051-7
- Baldock, M. R. J. (2004). *Self-Regulation of the Driving Behaviour of Older Drivers*. PhD, PhD Thesis, University of Adelaide, Adelaide, Australia. Retrieved from <http://digital.library.adelaide.edu.au/dspace/handle/2440/37930>
- Baldock, M. R. J., Kloeden, C. N., & McLean, A. J. (2008). *In-depth research into rural road crashes* (Report No. CASR057). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://digital.library.adelaide.edu.au/dspace/bitstream/2440/50534/1/CASR057.pdf>
- Borgialli, D. A., Hill, E. M., Maio, R. F., Compton, C. P., & Gregor, M. A. (2000). Effects of alcohol on the geographic variation of driver fatalities in motor vehicle crashes. *Academic Emergency Medicine*, 7(1), 7-13. doi: 10.1111/j.1553-2712.2000.tb01882.x
- Boschert, L., Pyta, V., Turner, B., & Green, D. (2010). *Road safety engineering risk assessment. Part 5: Review of crashes on unsealed roads* (Report No. AP-T150/10). Sydney: Austroads. Retrieved from <https://www.onlinepublications.austroads.com.au/items/AP-T150-10>
- Brown, L. H., Khanna, A., & Hunt, R. C. (2000). Rural vs urban motor vehicle crash death rates: 20 years of FARS data. *Prehospital Emergency Care*, 4(1), 7-13. doi: 10.1080/10903120090941551
- Corcoran, S., James, E. L., & Ellis, J. M. (2005). Do elderly Victorians in rural areas have access to public transport? *Road & Transport Research*, 14(1), 38-43. Retrieved from <http://www.arrb.com.au/Information-services/Publications/Issue.aspx?id=39>

Doecke, S., & Woolley, J. (2010). *Effective use of clear zones and barriers in a Safe System's context*. Paper presented at the Australasian Road Safety Research, Policing and

Education Conference, Canberra, Australian Capital Territory. Retrieved from

<http://acrs.org.au/files/arsrpe/R2010843.pdf>

Donaldson, A. E., Cook, L. J., Hutchings, C. B., & Dean, J. M. (2006). Crossing county lines:

The impact of crash location and driver's residence on motor vehicle crash fatality.

Accident Analysis and Prevention, 38(4), 723-727. doi: 10.1016/j.aap.2006.01.002

Gonzalez, R. P., Cummings, G. R., Phelan, H. A., Harlin, S., Mulekar, M., & Rodning, C. B.

(2007). Increased rural vehicular mortality rates: Roadways with higher speed limits

or excessive vehicular speed? *The Journal of Trauma*, 63(6), 1360-1363. doi:

10.1097/TA.0b013e31815b83b3

Hanrahan, R. B., Layde, P. M., Zhu, S., Guse, C. E., & Hargarten, S. W. (2009). The

association of driver age with traffic injury severity in Wisconsin. *Traffic Injury*

Prevention, 10(4), 361-367. doi: 10.1080/15389580902973635

Johnson, J. E. (1995). Rural elders and the decision to stop driving. *Journal of Community*

Health Nursing, 12(3), 131-138. doi: 10.1207/s15327655jchn1203_1

Langford, J. (2004). Why we continue to under-count the road toll. Sydney: Austroads.

Langford, J., & Koppel, S. (2006). The case for and against mandatory age-based assessment

of older drivers. *Transportation Research Part F*, 9(5), 353-362. doi:

10.1016/j.trf.2006.06.009

Li, G., Braver, E. R., & Chen, L. H. (2003). Fragility versus excessive crash involvement as

determinants of high death rates per vehicle-mile of travel among older drivers.

Accident Analysis and Prevention, 35(2), 227-235. doi: 10.1016/S0001-

4575(01)00107-5

Long, A. D., Kloeden, C. N., Hutchinson, T. P., & McLean, A. J. (2006). *Reduction of speed*

limit from 110km/h to 100km/h on certain roads in South Australia: a preliminary

- evaluation* (CASR024). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://casr.adelaide.edu.au/casrpublish/show.php?id=566>
- Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor vehicle crash mortality: The role of crash severity and medical resources. *Accident Analysis and Prevention*, 24(6), 631-642. doi: 10.1016/0001-4575(92)90015-B
- McTiernan, D., Thoresen, T., & McDonald, N. (2009). *Evaluation of the safety impact of centre-of-the-road wire rope barrier (WRB) on undivided rural roads* (Report No. AP-T135/09). Sydney: Austroads. Retrieved from <http://trid.trb.org/view.aspx?id=904620>
- Meuleners, L. B., Harding, A., Lee, A. H., & Legge, M. (2006). Fragility and crash overrepresentation among older drivers in Western Australia. *Accident Analysis and Prevention*, 38(5), 1006-1010. doi: 10.1016/j.aap.2006.04.005
- Muelleman, R. L., & Mueller, K. (1996). Fatal motor vehicle crashes: Variations of crash characteristics within rural regions of different population densities. *Journal of Trauma-Injury Infection and Critical Care*, 41(2), 315-320. Retrieved from http://journals.lww.com/jtrauma/Abstract/1996/08000/Fatal_Motor_Vehicle_Crashes_-Variations_of_Crash.20.aspx
- Muelleman, R. L., Wadman, M. C., Tran, T. P., Ullrich, F., & Anderson, J. R. (2007). Rural motor vehicle crash risk of death is higher after controlling for injury severity. *Journal of Trauma-Injury Infection and Critical Care*, 62(1), 221-226. doi: 10.1097/01.ta.0000231696.65548.06
- Ryan, G. A., Legge, M., & Rosman, D. (1998). Age related changes in driver's crash risk and crash type. *Accident Analysis and Prevention*, 30(3), 379-387. doi: 10.1016/S0001-4575(97)00098-5
- Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2010). *Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates*.

Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from
<http://acrs.org.au/files/arsrpe/R2010672.pdf>

Viano, D. C., Culver, C. C., Evans, L., & Frick, M. (1990). Involvement of older drivers in multivehicle side-impact crashes. *Accident Analysis and Prevention*, 22(2), 177-188.
doi: 10.1016/0001-4575(90)90068-V

Chapter 5: Study 3

Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation.

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Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013). Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation. *Journal of the Australasian College of Road Safety*, 24(1), 30-42. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRSjournalVol24No1Feb13WEBv2.pdf#page=30>

Preamble

The two preceding studies examined the safety of older drivers from rural areas of South Australia in comparison to those from urban areas. These studies involved examinations of crash, serious injury, and fatality rates and the environmental, driver and vehicle factors that increase the likelihood that older rural drivers will be seriously or fatally injured if they crash. Study 1 found that older rural drivers were more than twice as likely as older urban drivers to be seriously or fatally injured in a crash. Study 2 found that certain environmental variables, which were more likely to be present in the crashes of older rural drivers, increased the chances that the driver would be seriously or fatally injured.

In the literature review in Chapter 1 it was suggested that older drivers can potentially reduce their crash risk by self-regulating their driving behaviour. Self-regulation involves individuals assessing any deterioration in their driving, cognitive and functional abilities, as well as their health, and then adjusting their driving behaviour, either through an overall reduction in the amount of driving they do or by avoiding specific driving situations that they find difficult (e.g. driving on high-speed freeways). This then reduces a driver's exposure to difficult conditions and, consequently, their crash and injury risk, while maintaining some degree of mobility. Self-regulation may also include the decision to stop driving when an individual believes that they are no longer safe on the road.

Therefore, given the findings of the two preceding studies regarding their increased risk of serious or fatal injury, self-regulation may be particularly useful for older rural drivers as a strategy to avoid crash involvement and resulting injury. However, based on the literature reviewed in Chapter 2, it was hypothesised that older rural drivers would find it more difficult to practise self-regulation than their urban counterparts for several reasons. Firstly, driving is likely to be more important to rural residents because necessary community services (e.g. doctor, supermarket) and activities (e.g. church) are often further away than for urban

residents and only accessible by car. Secondly, the availability of alternative transportation (public transport, friends and family) is often more limited in rural areas. Therefore, older rural drivers may be more reluctant than urban drivers to reduce or stop driving because it would have a greater impact on their independence and lifestyle.

The following study was, therefore, designed to determine whether older rural drivers are restricted in their ability to self-regulate their driving because of the importance they attribute to driving and the reduced availability of alternative transportation in rural areas. In order to achieve this, a sample of 170 older drivers (aged ≥ 75) from rural and urban areas of South Australia completed a questionnaire examining the importance that they attribute to their driving, their access to alternative transportation, and the degree to which they self-regulate their driving.

**Do older rural drivers self-regulate their driving? The effects of increased driving
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Abstract

This study examined whether older rural drivers are restricted in the ability to self-regulate their driving by the importance they attribute to driving and reduced access to alternative transportation. A sample of 170 drivers (aged ≥ 75) from rural and urban areas of South Australia completed a questionnaire on driving importance, alternative means of transportation and driving self-regulation. Rural participants viewed driving as more important than urban participants and believed that they had less public transport available to them, used public transport less, and had fewer alternative means of transportation (e.g. taxi) available. However, they did not differ on various indices of self-regulation: avoidance of difficult driving situations, reductions in amount of driving and willingness to stop driving. Thus, older rural drivers' self-regulation does not appear to be restricted by increased driving importance or limited alternative transportation. However, limited alternative transportation is still viewed as a disadvantage to mobility.

Keywords: driving behaviour, older drivers, rural, self-regulation, transportation services, urban

Older drivers (generally defined as 65 years and older) have an elevated crash rate per kilometre driven (Baldock & McLean, 2005; Ryan, et al., 1998) and have an increased risk of being seriously or fatally injured if they are involved in a crash (Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meuleners, et al., 2006; Ryan, et al., 1998; Thompson, et al., 2010). However, it is important that older drivers do not cease driving prematurely because the mobility that driving provides is important to maintaining their independence and an active lifestyle (Adler, et al., 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Marottoli, et al., 2000). Moreover, a loss of mobility can lead to depression (Fonda, et al., 2001; Langford & Koppel, 2006a; Marottoli, Mendes de Leon, et al., 1997), a reduced network of friends (Mezuk & Rebok, 2008), and an increased risk of mortality in the ensuing 3-year period (Edwards, et al., 2009). Recent research has therefore emphasised the importance of older adults maintaining their driving mobility for as long as possible, provided it is safe for them to do so (Anderson, et al., 2009; Kostyniuk & Shope, 2003; Oxley & Whelan, 2008).

One way in which older adults can both prolong their driving mobility and potentially reduce their crash risk is by self-regulating their driving behaviour (Berry, 2011; Stalvey & Owsley, 2000). Self-regulation involves individuals assessing any deterioration in their driving, cognitive and functional abilities, as well as their health, and then adjusting their driving behaviour, either through an overall reduction in the amount of driving they do or by avoiding specific driving situations that an individual finds difficult (e.g. driving at night). This then reduces a driver's exposure to difficult conditions and, consequently, their crash and injury risk, while maintaining some degree of mobility. Self-regulation may also include the decision to stop driving when an individual believes that they are no longer safe on the road.

Ideally, greater self-regulation should be practised by those older drivers who are most at risk of being involved in a crash and of sustaining a serious or fatal injury in the event of a crash, with those drivers who are at a lower risk of these outcomes adopting fewer restrictions on their driving. Research by Thompson et al. (2010) has revealed that drivers who are aged

over 75 years and who live in rural areas of South Australia are more than twice as likely as their urban counterparts to be seriously or fatally injured when involved in a crash, suggesting that this is one group for whom self-regulation may be a useful strategy to avoid crash involvement and resulting injury. However, there are a number of reasons why older rural residents may find it more difficult to practice self-regulation than their urban counterparts. Firstly, rural residents are more likely to need to drive in order to access important community services (e.g. doctor, supermarket) and to maintain their community involvement. Consequently, they may be less willing to reduce or stop driving, as it would have a greater effect on their independence and lifestyle than would be the case for urban residents who have shorter distances to travel in order to access community services.

Secondly, self-regulation may be problematic in rural areas because access to public transport (Corcoran, et al., 2005), and the availability of friends and family to provide transportation (Johnson, 1995), is often more limited. Other transport options, such as community buses and taxis, are also less likely to be available, further increasing the importance of driving for older rural adults.

The aim of the present study was to determine whether older rural drivers are restricted in their ability to self-regulate their driving by the importance they attribute to driving and the availability of alternative transportation in rural areas. To date, there has not been any research that has examined this issue, but it is an important issue because restrictions in a person's ability to self-regulate reduces the level of control that they have over their safety on the road. Furthermore, it is important to understand the possible causes, in order to determine whether they can be addressed.

Method

Participants

Participants were recruited through an appeal to people who attended the South Australian Royal Automobile Association's (RAA) "Years Ahead" community presentations. The RAA is an independent automobile club in SA, which has approximately 560,000 members and provides a range of services, including road safety information. The "Years Ahead" presentations are given at churches and senior citizens' clubs in both rural and urban areas of South Australia, and provide information on road safety that is specifically relevant to older adults. One of the researchers (JPT) attended these presentations, spoke about the research, and invited individuals to participate.

To be eligible, participants had to be aged 75 years or older. This age range was chosen to define an "older driver" based on a previous study (Thompson, et al., 2010), which found that drivers 75 years and older were significantly more likely to be seriously or fatally injured when involved in a crash than drivers below this age. In addition, participants were required to hold a valid driver's licence for a car, drive reasonably regularly (i.e. more than once in the previous month), and be fluent in English (in order to complete the questionnaire).

A total of 170 eligible participants (71 females, 99 males) completed the study questionnaire. Of these, 64 (38%; 27 females, 37 males) resided in rural areas and 106 (62%; 44 females, 62 males) lived in urban areas of South Australia. Urban areas of South Australia were defined as the capital city, Adelaide, and a surrounding 5-20 kilometre region, while rural areas were defined as those outside of the Adelaide area but within a two hour drive from the centre of Adelaide (a radius of approximately 100kms). The age of the participants ranged from 75 to 94, with a mean of 79.9 years ($SD = 4.0$). The mean age of the rural participants was 79.1 years ($SD = 3.8$), while for the urban participants it was 80.5 years ($SD = 4.0$).

The sample was compared to data on licensed drivers aged 75 and over in South Australia for the year 2009⁷ to determine whether it was representative of the older driver population. The data were obtained from the South Australian Department of Planning, Transport and Infrastructure for the year 2009 and for individuals with a class C driver's licence (able to drive non-commercial motor vehicles not exceeding 4,500kg). There were 60,602 licensed drivers aged 75 and over in South Australia in 2009, 28% from rural areas and 72% from urban areas. Eighty-three per cent of these older drivers were in the 75-84 age group and 17% in the 85 and over group, compared to 86% and 14% for the current sample. Therefore, the age composition of the sample closely approximates that of the population of South Australia.

Measure

Participants completed a 'Driving Patterns Questionnaire' (DPQ)⁸. The DPQ was developed and trialled specifically for use in the present research because no other appropriate measures could be located. It was divided into four parts (background information, driving importance, alternative means of transportation, and driving self-regulation). The first part sought background information on the participants, including the postcode for their home residence (four digit code, used to determine whether they lived in a rural or urban area); age (in years) and gender; highest level of education that they had completed (six options: some secondary or high school, completed high school, trade/technical college, certificate or diploma, university degree, postgraduate degree); and whether they held a valid driver's licence for a car (yes or no) and had driven in the last month.

The *Driving Importance* section included six items asking participants to report how strongly they agreed with statements indicating that driving is important for various reasons, such as for independence (for a full list see Table 1 in the Results section). Each item was

⁷ This was the most recent data available.

⁸ A copy of the complete questionnaire is provided in Appendix A.

rated on a four-point scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). Responses to these items were aggregated to provide an overall measure of driving importance, with scores potentially ranging from 6 (not important) to 24 (extremely important).

The *Alternative Means of Transportation* section asked participants whether convenient public transportation was available (yes or no) to get them to four common destinations (doctor, supermarket, friends and family, and social activities). The “yes” responses were summed for each participant to provide an overall ‘availability of public transportation’ score, ranging from 0 to 4. Next, participants indicated how often they used public transportation using a four-point scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often). They also had to indicate which of seven other alternative means of transportation, such as taxis, they believed would be available to them if they had to stop driving (for a full list see Table 3 in the Results section). A total ‘available alternative means of transportation’ score was then calculated for each participant by tallying the options that were marked, ranging from 0 (no alternative means) to an uncapped number because “other” (i.e. any number of alternative means that they believed would be available to them) was included.

The final section, *Driving Self-Regulation*, asked the participants to rate their level of avoidance during the past year of nine difficult driving situations, such as driving at night (for a full list see Table 4 in the Results section), using a five-point scale (1 = never avoid, 2 = rarely avoid, 3 = sometimes avoid, 4 = often avoid, 5 = always avoid). The sum of the ratings for these items provided an overall driving avoidance score, ranging from 9 (never avoid any driving situations) to 45 (always avoid all nine difficult driving situations). These questions have been widely used in previous research on older drivers to measure self-regulation (Baldock, Mathias, McLean, & Berndt, 2006a; Baldock, Mathias, McLean, & Berndt, 2006b; Baldock, Thompson, & Mathias, 2008; Stalvey & Owsley, 2000). Indeed, this was the only part of the DPQ that was not developed specifically for the present research and was chosen

so that the results could be compared to existing research. Next, participants had to specify how much they had reduced the amount that they drove in the past year, choosing from four options (not at all, somewhat, reasonably, greatly). A four-point scale was applied to these options (0 = not at all to 3 = greatly). Finally, they had to specify the degree to which they agreed with statements indicating that they would stop driving given certain situations, such as their doctor recommending it (for a full list see Table 5 in the Results section), using a four-point scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The aggregate of the responses to these five items provided an overall measure of participants' willingness to stop driving, with scores ranging from 5 (not willing) to 20 (completely willing).

Procedure and statistical analyses

The attendees at the "Years Ahead" presentations who agreed to participate were provided with a copy of the questionnaire, an information sheet about the research⁹, two copies of a consent form¹⁰, and a reply-paid envelope. The questionnaire was completed by the participant at home and mailed back to the first investigator (JPT), along with one of the signed consent forms (the other was kept by the participant). Ethics approval for the research was granted by the Human Research Ethics Subcommittee in the School of Psychology at the University of Adelaide. Prior to completing the questionnaire, the participants were reminded that they could withdraw from the study at any stage and assured that their responses would remain confidential.

The data obtained from the questionnaires were used to compare the rural and urban participants to determine whether there were any differences between them in terms of (a) the importance of driving, (b) the public transportation available to them, (c) their usage of public

⁹ A copy of the information sheet for the questionnaire section of this research is provided in Appendix B.

¹⁰ A copy of the consent form for the questionnaire section of this research is provided in Appendix C.

transportation, (d) the other alternative means of transportation available to them, and (e) their driving self-regulation (in terms of avoidance of difficult driving situations, reductions in amount of driving in the past year and willingness to stop driving given reasons to do so).

Independent samples *t*-tests were used for these between-group comparisons (rural, urban), except for the comparisons of their usage of public transportation and the amount that they had reduced their driving in the past year, as these were measured on ordinal scales, consequently, chi-square tests were used. Cohen's *d* effect sizes were calculated for the *t*-tests to evaluate the magnitude of any group differences, with *d* = .2, .5 and .8 equating to small, medium and large effect sizes, respectively (Cohen, 1992).

Finally, rural and urban older drivers were also compared to determine whether they differed in terms of the effect that driving importance, availability of public transportation, usage of public transportation and availability of other alternative means of transportation had on the degree to which they self-regulate their driving. For this comparison, the measures of driving importance, availability of convenient public transportation, usage of public transportation, and availability of other alternative means of transportation were used as independent variables in each of three regression models. Linear regression was used in models 1 and 2, with the overall measure of avoidance of difficult driving situations as the dependent variable in model 1 and the overall measure of willingness to stop driving in model 2. In model 3 the dependent variable was the measure of driving reduction in the past year. However, this measure used an ordinal four-point scale, which limited the variance. Therefore, logistic regression was used with the data treated as a binary variable, namely whether the participants did (i.e. a response of "somewhat", "reasonably" or "greatly") or did not reduce their driving (i.e. response "not at all").

The three models were examined separately for rural and urban participants (total of six analyses) so that the effects of the independent variables on the three dependent variables could independently be determined for each group and then compared. The age of the

participants was also entered as an independent variable in the models because older age has been shown to be associated with increased self-regulation (Charlton, et al., 2006; Forrest, et al., 1997; Gallo, et al., 1999; Raitanen, et al., 2003; Rimmo & Hakamies-Blomqvist, 2002) and could therefore mediate the effects of the other independent variables on the three dependent variables.

For all analyses, an alpha level of .05 was used to determine statistical significance. All analyses were two-tailed in order to identify significant differences between the rural and urban groups in either direction.

Results

Demographic comparison of rural and urban drivers

The age, education, and gender composition of the rural and urban groups were initially compared to assess whether there were any demographic differences between the two groups. These analyses revealed that there were no significant differences between the two groups in terms of their level of education, $t(163) = .58, p = .561$, or gender, $\chi^2(1, N = 170) = .01, p = .931$. While the urban participants had a significantly higher mean age (80.5, $SD = 4.0$) than the rural participants (79.1, $SD = 3.8$), $t(168) = 2.26, p = .025$, the difference of only one year equates to a small effect size (Cohen's $d = .36$) and is unlikely to be of practical significance in terms of driving behaviour.

Driving importance

The mean overall driving importance scores for the rural (20.4, $SD = 3.0$) and urban participants (19.5, $SD = 2.8$) were both high, given that scores could range from 6 to 24. The difference between these means was small ($d = .34$) but significant, $t(153) = 2.07, p = .040$, suggesting that driving was more important to meeting the day-to-day needs of older rural

drivers. Responses to the individual items are summarised in Table 1, where it can be seen that the greatest differences between rural and urban participants were for the three items relating to the availability of other sources of transportation (public transport, friends, family), with more rural participants strongly agreeing with statements that these sources were not available to them and more urban participants disagreeing with these statements.

Table 1
Perceived Importance of Driving for Six Reasons: Rural and Urban Responses

Reason		Level of Agreement (%)			
		Strongly disagree	Disagree	Agree	Strongly agree
For accessing necessary services (e.g. doctor)	Rural	1.7	5.2	37.9	55.2
	Urban	1.0	2.1	39.2	57.7
Because public transportation is unavailable	Rural	3.4	3.4	34.5	58.6
	Urban	6.2	30.9	40.2	22.7
Because friends are unavailable to provide transportation	Rural	3.4	8.6	43.1	44.8
	Urban	7.2	21.6	42.3	28.9
Because family are unavailable to provide transportation	Rural	5.2	12.1	44.8	37.9
	Urban	6.2	22.7	46.4	24.7
For independence	Rural	0.0	0.0	43.1	56.9
	Urban	0.0	0.0	25.8	74.2
For community involvement/ active lifestyle	Rural	0.0	5.2	43.1	51.7
	Urban	1.0	1.0	39.2	58.8

Note. Six rural and nine urban participants did not give valid responses to these items. Therefore, $n = 155$ for these analyses, 58 rural and 97 urban.

Alternative means of transportation

In terms of the overall availability of public transportation, rural participants had a mean score (0.7 , $SD = 1.3$), which indicates low levels of availability (possible range: 0 - 4), compared to that of urban participants (1.2 , $SD = 1.3$), who also reported relatively low scores. The difference between these means was small-medium in size ($d = .44$) and significant, $t(161) = 2.74$; $p = .007$, indicating that older adults from rural areas have moderately less public transportation available to them than those from urban areas. This was

also reflected in the responses to the individual items in the measure (see Table 2), with particularly large differences in access to transport that would enable residents to get to supermarkets.

Table 2
Percentages of Rural and Urban Participants who Indicated that Convenient Public Transportation was Available to get them to Four Common Destinations

Destination		%
Doctor	Rural	14.5
	Urban	29.7
Supermarket	Rural	17.7
	Urban	51.5
Friends and family	Rural	16.1
	Urban	15.8
Social activities	Rural	16.1
	Urban	24.8

Note. Two rural and five urban participants did not give valid responses to these items. Therefore, $n = 163$ for these analyses, 62 rural and 101 urban.

In terms of the amount that the rural participants used public transportation, 46.0% reported “never” using it, 36.5% reported “rarely”, 14.3% reported “sometimes”, and 3.2% reported “often”. For the urban participants, 2.9% reported “never” using it, 33.3% reported “rarely”, 56.2% reported “sometimes”, and 7.6% reported “often”. Therefore, more rural than urban participants responded with “never” and “rarely”, while more urban participants responded with “sometimes” and “often”. Moreover, there was a significant association between rural/urban residence and use of public transportation, $\chi^2(3, n = 168) = 57.04, p < .001$, with the Cramer’s V statistic of .58 indicating that 34% of the variation in usage by older adults was explained by whether they lived in a rural or urban area. Thus, older rural drivers appear to use public transportation less than their urban counterparts.

Rural participants reported that they had an average of 2.4 ($SD = 1.0$) alternative means of transportation available to them if they needed to stop driving, which was significantly fewer than the average number available to urban participants (mean = 3.2, $SD =$

1.3), $t(167) = 4.10$; $p < .001$, $d = .67$. Older rural drivers therefore have fewer alternative means of transportation available to them. This was reflected in the responses regarding the availability of each individual alternative means of transportation (see Table 3), where, for most of the options, fewer rural participants reported that they were available than urban participants. The biggest difference was for public transportation, which supports the earlier finding that rural participants had less public transportation available to them. Unexpectedly, however, more rural participants indicated that their partner was available to drive them.

Table 3

Alternative Means of Transportation: Percentages of Participants (Rural and Urban) who Indicated that the Relevant Option was Available to them

Alternative means of transportation		%
Community transportation	Rural	31.3
	Urban	46.7
Public transportation	Rural	34.4
	Urban	88.6
Friends could drive me	Rural	37.5
	Urban	35.2
Family could drive me	Rural	35.9
	Urban	50.5
Husband/wife/partner could drive me	Rural	54.7
	Urban	37.1
Taxi	Rural	34.4
	Urban	48.6
Other ^a	Rural	9.4
	Urban	9.5

Note. One urban participant did not give a valid response to this item. Therefore, $n = 169$ for these analyses, 64 rural and 105 urban.

^a“Other” responses included using a gopher, walking, and riding a bicycle.

Driving self-regulation

When the extent to which rural and urban drivers were using self-regulation to limit their exposure to risky driving situations was compared, it was found that rural participants had an overall mean of 17.6 ($SD = 7.4$) on the measure of avoidance of difficult situations,

while the urban participants had a mean of 15.8 ($SD = 6.7$). Both rural and urban scores were low (possible range: 9 - 45) and the difference between the means was not significant, $t(161) = 1.55$; $p = .123$, $d = .25$; indicating that neither group actively self-regulates their driving. Indeed, the levels of avoidance reported for each of the difficult situations individually (see Table 4) were similar for rural and urban participants.

Table 4
Avoidance of Individual Difficult Driving Situations: Rural and Urban Responses

Driving situation		Level of Avoidance (%)				
		Never	Rarely	Sometimes	Often	Always
In the rain	Rural	57.1	20.6	19.0	3.2	0.0
	Urban	65.0	20.0	13.0	2.0	0.0
When alone	Rural	82.5	7.9	7.9	1.6	0.0
	Urban	91.0	6.0	3.0	0.0	0.0
Parallel parking	Rural	34.9	20.6	19.0	15.9	9.5
	Urban	47.0	21.0	19.0	6.0	7.0
Right turns	Rural	54.0	28.6	14.3	0.0	3.2
	Urban	60.0	23.0	13.0	3.0	1.0
Freeways	Rural	68.3	17.5	4.8	7.9	1.6
	Urban	73.0	12.0	8.0	6.0	1.0
High traffic roads	Rural	55.6	15.9	15.9	11.1	1.6
	Urban	61.0	19.0	16.0	4.0	0.0
Peak hour	Rural	42.9	12.7	20.6	11.1	12.7
	Urban	45.0	27.0	21.0	7.0	0.0
At night	Rural	38.1	22.2	23.8	6.3	9.5
	Urban	53.0	15.0	9.0	9.0	14.0
At night in the rain	Rural	46.0	12.7	23.8	3.2	14.3
	Urban	49.0	16.0	10.0	5.0	20.0

Note. One rural and six urban participants did not give valid responses to these items. Therefore, $n = 163$ for these analyses, 63 rural and 100 urban.

In terms of the amount that the rural participants had reduced their driving in the past year, 57.1% reported “not at all”, 20.6% reported “somewhat”, 14.3% reported “reasonably”, and 7.9% reported “greatly”. For the urban participants, 50.9% reported “not at all”, 34.0%

reported “somewhat”, 10.4% reported “reasonably”, and 4.7% reported “greatly”. Thus, the responses to this question were similar for rural and urban participants. Indeed, a $2 \times 4 \chi^2$ showed no significant association between rural/urban residence and any reduction in driving, $\chi^2(3, n = 169) = 3.91, p = .272$, with a small Cramer’s V statistic of .27.

In terms of overall willingness to stop driving, the mean scores for both rural ($16.8, SD = 1.8$) and urban participants ($16.4, SD = 2.4$) were high (possible range: 5 - 20). The difference between the means was not significant, $t(151) = 1.23; p = .222, d = .21$, suggesting that older rural and urban drivers do not differ in their willingness to stop driving. Indeed, the responses to the specific reasons to stop driving were similar for rural and urban participants (see Table 5).

Table 5

Willingness to Stop Driving for Five Reasons: Rural and Urban Responses

Reason to stop driving		Level of Agreement (%)			
		Strongly disagree	Disagree	Agree	Strongly agree
Doctor recommendation	Rural	0.0	3.4	56.9	39.7
	Urban	1.1	3.2	55.8	40.0
Friends and family recommendation	Rural	3.4	15.5	56.9	24.1
	Urban	5.3	20.0	56.8	17.9
Not confident enough	Rural	0.0	1.7	56.9	41.4
	Urban	1.1	4.2	50.5	44.2
Health and driving abilities not at safe level	Rural	0.0	0.0	39.7	60.3
	Urban	0.0	0.0	45.3	54.7
Caused a serious accident	Rural	0.0	10.3	36.2	53.4
	Urban	1.1	14.7	46.3	37.9

Note. Six rural and eleven urban participants did not give valid responses to these items. Therefore, $n = 153$ for these analyses, 58 rural and 95 urban.

Prediction of levels of self-regulation of driving

The first regression model, which examined the effects of the independent variables (driving importance, availability of convenient public transportation, usage of public transportation, and availability of other alternative means of transportation) on avoidance of

difficult driving situations, was not statistically significant for the rural, $F(5, 51) = .73; p = .603$, or urban participants, $F(5, 83) = 1.52; p = .194$, with the independent variables only accounting for < 0.1% of the variance in avoidance of difficult driving situations in both groups (adjusted R^2). It can be seen from Table 6 that age had a significant effect on the self-regulation of urban but not for rural drivers, while none of the other independent variables had any significant effects.

The second regression model, which examined the effects of the independent variables on willingness to stop driving, was also not significant for the rural, $F(5, 48) = .60; p = .704$, or urban participants, $F(5, 81) = 1.81; p = .121$, with the independent variables only accounting for < 0.1% of the variance in willingness to stop driving in both groups (adjusted R^2). However, in Table 6 it can be seen that the effect of the variable 'availability of other alternative means of transportation', while not significant for rural drivers, was significant for urban drivers ($p = .016$). For every additional means of transportation available to an older urban driver, their willingness to stop driving increased by 0.49 of a unit on the scale of 5 to 20. This suggests that the availability of alternative means of transportation has an effect on willingness to stop driving for older urban drivers but not for older rural drivers.

Finally, the third regression model, which examined the effects of the independent variables on whether an older driver would reduce their driving or not, was also not statistically significant for the rural, $\chi^2(5, n = 57) = 1.93; p = .859$, or urban participants, $\chi^2(5, n = 90) = 6.02; p = .304$. The independent variables only accounted for < 0.1% of the variance in driving reduction in both groups (Cox & Snell R^2). None of the independent variables significantly predicted whether an older driver would or would not reduce their driving (see Table 6).

Table 6
Results of Linear Regression to Predict Avoidance of Difficult Driving Situations (Model 1) and Willingness to Stop Driving (Model 2), and Logistic Regression to Predict Driving Reduction in the Past Year (Model 3), for Rural and Urban Participants Separately

		Independent variable	B ^a	Beta ^b	t	p-Value
Model 1	Rural	Driving importance	0.39	0.16	1.12	0.268
		Avail. of public transportation	0.81	0.14	1.00	0.323
		Usage of public transportation	0.43	0.05	0.35	0.727
		Avail. of alternative transportation	0.85	0.12	0.84	0.403
		Age	0.01	<0.01	0.02	0.986
	Urban	Driving importance	-0.04	-0.02	-0.14	0.890
		Avail. of public transportation	-0.26	-0.05	-0.40	0.693
		Usage of public transportation	1.00	0.10	0.89	0.374
		Avail. of alternative transportation	0.58	0.11	1.01	0.315
		Age	0.48	0.27	2.48	0.015*
Model 2	Rural	Driving importance	0.11	0.18	1.19	0.242
		Avail. of public transportation	-0.09	-0.06	-0.40	0.689
		Usage of public transportation	0.04	0.02	0.13	0.898
		Avail. of alternative transportation	0.20	0.12	0.78	0.439
		Age	0.03	0.06	0.42	0.679
	Urban	Driving importance	-0.07	-0.08	-0.70	0.488
		Avail. of public transportation	0.07	0.03	0.29	0.771
		Usage of public transportation	0.30	0.09	0.78	0.440
		Avail. of alternative transportation	0.49	0.27	2.47	0.016*
		Age	0.07	0.12	1.09	0.280
Model 3	Rural		B ^a	Odds ratio	Wald	p-Value
		Driving importance	<0.01	1.00	<0.01	0.973
		Avail. of public transportation	-0.30	0.74	1.32	0.252
		Usage of public transportation	-0.19	0.83	0.28	0.598
		Avail. of alternative transportation	-0.01	0.99	<0.01	0.984
		Age	-0.01	0.99	0.02	0.886
	Urban	Driving importance	-0.04	0.97	0.15	0.696
		Avail. of public transportation	-0.11	0.90	0.33	0.568
		Usage of public transportation	0.50	1.65	2.08	0.149
		Avail. of alternative transportation	0.10	1.11	0.36	0.547
		Age	0.11	1.12	3.42	0.065

^aThe results for B are unstandardised coefficients.

^bThe results for Beta are standardised coefficients.

* $p < .05$.

Discussion

This study demonstrated that driving is perceived to be more important to meeting the day-to-day needs of older rural drivers than it is to older urban drivers. It also found that older rural drivers report that public transportation and other alternative means of transportation are not as readily available to them. Indeed, the main reasons for driving being more important to older rural drivers were the limited availability of public transportation, and friends and family who could assist with their transport needs.

A comparison of the importance that is placed on driving by older drivers from rural and urban areas has not previously been undertaken and, therefore, this is the first time that the greater importance of driving to older rural drivers has been demonstrated empirically. Similar findings have previously been reported regarding the availability of alternative means of transportation. Corcoran et al. (2005) for example, found that public transportation was limited for people aged over 65 years living in a rural region of Victoria, Australia. In addition, a survey of older adults from rural areas in the USA by Johnson (1995) indicated that their friends and family often lived a long distance away, making assistance with transportation difficult. Interestingly, in the current study, more rural participants suggested that their partner was available to provide transportation. In contrast, the availability of community transport and taxis for rural and urban older persons has not been previously compared. More rural participants indicated that neither were readily available to them.

The limited availability of public transportation is likely to be responsible for the finding that rural participants were using it less frequently. For the urban participants, public transportation options were greater, as was their usage of it, suggesting that older adults increase their usage of public transportation when it is available.

Based on the importance of driving for older rural drivers and the limited availability of alternative transportation, it might be expected that they would be less able to avoid, reduce

or stop driving. However, older rural drivers did not differ from older urban drivers in their avoidance of difficult driving situations, the amount that they had reduced their driving in the past year, or their willingness to stop driving. This suggests that they are able to self-regulate their driving to a similar degree as older urban drivers and that they are not restricted in doing so by the greater importance that they place on driving or the limited alternative transportation that is available to them. Indeed, based on the multivariate analyses, it appears that driving importance, the availability of public transportation, usage of public transportation and the availability of other alternative means of transportation do *not* affect the degree to which older drivers from rural and urban areas self-regulate. However, the availability of other alternative means of transportation did affect the willingness of urban drivers to stop driving. This is consistent with the finding of Choi, Adams and Kahana (2012) who also reported that older adults are more likely to stop driving if they have transport support from friends and neighbours, as well as other organisations, such as churches.

Study limitations and future directions

There were several limitations to this study. Firstly, self-report measures can be unreliable, as the participants may accidentally report inaccurate information. They may also attempt to portray a socially desirable account of themselves through the information that they provide. For example, they may report that they are more willing to stop driving than would perhaps actually be the case, which may have affected the results.

The samples of rural and urban participants were small for the purposes of the regression analysis, which had multiple independent variables, thereby limiting statistical power. In addition, there are other factors, which were not assessed in this study, that may affect the extent to which older drivers are able to avoid, reduce or stop driving. These include the distance from the participants' residences to necessary services, as well as to their friends and family, and whether recommendations to avoid, reduce or stop driving had been made to

the participants by their friends, family or doctor. These variables and their effect on self-regulation should be examined in future research on this topic.

The rural participants were recruited from regions that were relatively close to the capital city (i.e. within approximately two hours driving distance). For practical reasons, it was not possible to recruit older drivers from more remote areas of the state. Driving is likely to be even more important to persons from remote areas and alternative transportation is likely to be more limited, making it even harder for persons living in more remote rural areas to avoid, reduce or stop driving. If individuals from remote areas had participated, it may have affected the findings relating to self-regulation. People living in remote areas should therefore also be recruited in future research, if at all possible.

The majority of both rural and urban participants indicated that they “never” or “rarely” avoided each of the difficult driving situations, reducing the variability in the scores for this measure. Other studies have also found low levels of avoidance using the same measure (Baldock, et al., 2006a; Baldock, et al., 2006b; Stalvey & Owsley, 2000; Sullivan, et al., 2011). While the low scores may truly suggest that older drivers do not generally avoid these situations, they may also result from limitations in the measure.

Sullivan et al. (2011) encountered a similar problem when measuring avoidance of difficult driving situations. They recommended that the items in the measure should be reconsidered as they may not be the only situations which older drivers avoid. However, this was published after the design and data collection stages of the present study. The participants in the Sullivan et al. study were required to report which situations they view as safe and unsafe. Although this process did identify the situations that were used in the current measure as being unsafe, thereby validating their inclusion here, a range of other situations were also identified as unsafe. Sullivan et al. suggested that these additional unsafe situations could be included in a modified scale. It is likely that the present research would have benefitted from such a modified scale, particularly as some of the situations in the current scale (e.g. driving

in peak hour) may not apply to older rural drivers. Furthermore, some of the current situations (e.g. parallel parking) can be avoided in everyday driving, without having to resort to using alternative transportation, and are unlikely to be affected by perceptions of driving importance. These items should therefore be reconsidered in future studies that examine driving importance and alternative transportation. Of the items suggested by Sullivan et al., those that are likely to have been most useful to the present study are: ‘long distance driving’, ‘driving in foggy conditions’, ‘driving when other drivers might endanger me’ and ‘driving when I think other drivers will put me at risk’.

The low rates of self regulation reported here may also reflect that the convenience sample was recruited through senior citizens’ clubs and churches. Such people, and particularly those willing to volunteer for the study, may be more active, healthy and community-minded than typical adults in the same age group. In addition, they had to travel from their homes to the meeting location, suggesting that they are amongst the more mobile older residents. Past research has shown that the degree to which older drivers self-regulate is associated with their health, medical conditions and certain functional and cognitive abilities (Baldock, et al., 2006b; Ball, et al., 1998; Charlton, et al., 2006; Owsley, et al., 1999). The participants in the present study may not have needed to self-regulate as much because they were healthy and highly functioning; variables that were not measured in the current study. Future research would benefit from undertaking a brief assessment of the functional and cognitive abilities of the sample, as well as by recruiting participants with a broad range of health and cognitive and functional abilities, including those with impairments in these abilities. It would also benefit from recruiting people who have reduced mobility (i.e. not just those who are mobile enough to attend community meetings). This may provide a better indication of whether rural older drivers are able to self-regulate appropriately. Despite this, however, the sample was found to be representative of the older driver population in South Australia in terms of age composition.

It should also be noted that the participants were recruited from a driving safety presentation designed specifically for older adults. As a result, there may have been a degree of bias in the sample because older adults who are conscientious enough to attend such a presentation may be more mindful of driving safety and, therefore, may not be representative of all older drivers. Furthermore, they may have had a greater awareness of issues relating to road safety when they completed the questionnaire because they had recently attended the ‘Years Ahead’ presentation. Therefore, it may have been anticipated that they would report a high degree of self-regulation in order to present themselves as safe drivers. However, any such effects would have been equivalent across the rural and urban groups. Moreover, as discussed above, the levels of self-regulation for both groups were low. Consequently, it is unlikely that this sample bias had any considerable effects on the outcomes of the study.

Finally, the scores for the measure of changes to the amount of driving in the past year were also low, with around half of the participants reporting that they had not reduced their driving during this period. This may also have been due to a healthy and highly functioning sample who did not need to reduce their driving. It may also reflect limitations with the measure. Specifically, participants were required to provide ratings using a scale that only included four nominal responses (i.e. not at all, somewhat, reasonably, greatly), which provided limited detail regarding the exact amount of change. In addition, retrospective estimation over the past year may be prone to error. Future research would benefit from a more detailed assessment of these changes to driving patterns.

Conclusion

Overall, rural and urban older drivers were not found to differ in the degree to which they self-regulate their driving. Given that older rural drivers are more than twice as likely as their urban counterparts to be seriously or fatally injured in a crash (Thompson, et al., 2010),

there may be a greater need for these drivers to adjust their driving behaviour in order to maintain their safety. It may be beneficial, therefore, to encourage older rural drivers to increase their self-regulation. Particular emphasis could be given to assisting them to adjust their driving in such a way that it has the least detrimental effect on their mobility, while providing the best safety outcomes.

Although the availability of public transport and other alternative means of transportation did not affect the degree to which older drivers self-regulate, it is important to provide a transportation system that adequately meets the needs of older adults and supports drivers in their decision to adjust, reduce or stop driving as their circumstances change. This study suggests that older rural adults are disadvantaged in terms of public transportation and other alternatives. A solution would be to increase public transportation services (e.g. buses, trains) or subsidise private services (e.g. taxis) in rural areas. While it may be feasible to increase public transport options in large rural communities, the cost may be prohibitive in smaller communities. Alternatively, local councils, as well as independent groups, such as churches and senior citizens clubs, could be encouraged to increase their provision of community-run transportation services (e.g. community buses that transport people to organised destinations or volunteer driver systems). These services not only reduce the reliance on the personal automobile but are also convenient and encourage community participation.

References

- Adler, G., Rottunda, S., & Kuskowski, M. (1999). Dementia and driving: Perceptions and changing habits. *Clinical Gerontologist*, 20(2), 23-35. doi: 10.1300/J018v20n02_03
- Anderson, R., Anstey, K. J., & Wood, J. (2009). The right approach for older drivers. *Journal of the Australasian College of Road Safety*, 20(3), 37-39. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-20-No3Website1.pdf>
- Baldock, M. R. J., Mathias, J. L., McLean, A. J., & Berndt, A. (2006a). Self-regulation of driving and its relationship to driving ability among older adults. *Accident Analysis and Prevention*, 38, 1038-1045. doi: 10.1016/j.aap.2006.04.016
- Baldock, M. R. J., Mathias, J. L., McLean, J., & Berndt, A. (2006b). Self-regulation of driving and older drivers' functional abilities. *Clinical Gerontologist*, 30(1), 53-70. doi: 10.1300/J018v30n01_05
- Baldock, M. R. J., & McLean, A. J. (2005). *Older drivers: Crash involvement rates and causes* (Report No. CASR015). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://digital.library.adelaide.edu.au/dspace/bitstream/2440/36418/1/CASR015.pdf>
- Baldock, M. R. J., Thompson, J. P., & Mathias, J. L. (2008). *Self-regulation of driving behaviour among older drivers: Findings from a five year follow-up*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Adelaide, South Australia. Retrieved from <http://acrs.org.au/files/arsrpe/RS080117.pdf>
- Ball, K., Owsley, C., Stalvey, B., Roenker, D. L., Sloane, M. E., & Graves, M. (1998). Driving avoidance and functional impairment in older drivers. *Accident Analysis and Prevention*, 30(3), 313-322. doi: 10.1016/S0001-4575(97)00102-4

- Berry, C. (2011). *Can older drivers be nudged? How the public and private sectors can influence older drivers' self-regulation*. London: RAC Foundation. Retrieved from http://www.racfoundation.org/assets/rac_foundation/content/downloadables/older_drivers_nudge-main_report-berry.pdf
- Charlton, J. L., Oxley, J., Fildes, B., Oxley, P., Newstead, S., Koppel, S., & O'Hare, M. (2006). Characteristics of older drivers who adopt self-regulatory driving behaviours. *Transportation Research Part F, 9*(5), 363-373. doi: 10.1016/j.trf.2006.06.006
- Choi, M., Adams, K. B., & Kahana, E. (2012). The impact of transportation support on driving cessation among community-dwelling older adults. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 67*(3), 392-400. doi: 10.1093/geronb/gbs035
- Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159. doi: 10.1037/0033-2909.112.1.155
- Corcoran, S., James, E. L., & Ellis, J. M. (2005). Do elderly Victorians in rural areas have access to public transport? *Road & Transport Research, 14*(1), 38-43. Retrieved from <http://www.arrb.com.au/Information-services/Publications/Issue.aspx?id=39>
- De Raedt, R., & Ponjaert-Kristoffersen, I. (2000). The relationship between cognitive/neuropsychological factors and car driving performance in older adults. *Journal of the American Geriatrics Society, 48*(12), 1664-1668. Retrieved from <http://psycnet.apa.org/psycinfo/2000-12632-014>
- Edwards, J. D., Perkins, M., Ross, L. A., & Reynolds, S. L. (2009). Driving status and three-year mortality among community-dwelling older adults. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences, 64A*(2), 300-305. doi: 10.1093/gerona/gln019

- Fonda, S. J., Wallace, R. B., & Herzog, A. R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *Journal of Gerontology: Social Sciences*, 56B(6), S343-S351. doi: 10.1093/geronb/56.6.S343
- Forrest, K. Y., Bunker, C. H., Songer, T. J., Coben, J. H., & Cauley, J. A. (1997). Driving patterns and medical conditions in older women. *Journal of the American Geriatrics Society*, 45(10), 1214-1218. Retrieved from <http://europepmc.org/abstract/MED/9329483>
- Gallo, J. J., Rebok, G. W., & Lesikar, S. E. (1999). The driving habits of adults aged 60 years and older. *Journal of the American Geriatrics Society*, 47(3), 335-341. Retrieved from <http://psycnet.apa.org/psycinfo/1999-10561-006>
- Hanrahan, R. B., Layde, P. M., Zhu, S., Guse, C. E., & Hargarten, S. W. (2009). The association of driver age with traffic injury severity in Wisconsin. *Traffic Injury Prevention*, 10(4), 361-367. doi: 10.1080/15389580902973635
- Johnson, J. E. (1995). Rural elders and the decision to stop driving. *Journal of Community Health Nursing*, 12(3), 131-138. doi: 10.1207/s15327655jchn1203_1
- Kostyniuk, L. P., & Shope, J. T. (2003). Driving and alternatives: Older drivers in Michigan. *Journal of Safety Research*, 34(4), 407-414. doi: 10.1016/j.jsr.2003.09.001
- Langford, J., & Koppel, S. (2006). The case for and against mandatory age-based assessment of older drivers. *Transportation Research Part F*, 9(5), 353-362. doi: 10.1016/j.trf.2006.06.009
- Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., & Berkman, L. F. (2000). Consequences of driving cessation: Decreased out-of-home activity levels. *Journal of Gerontology: Social Sciences*, 55B(6), S334-S340. doi: 10.1093/geronb/55.6.S334
- Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive

- symptoms: Prospective evidence from the New Haven Established Populations for Epidemiological Studies of the Elderly. *Journal of the American Geriatrics Society*, 45(2), 202-206. Retrieved from <http://psycnet.apa.org/psycinfo/1997-07396-004>
- Meuleners, L. B., Harding, A., Lee, A. H., & Legge, M. (2006). Fragility and crash overrepresentation among older drivers in Western Australia. *Accident Analysis and Prevention*, 38(5), 1006-1010. doi: 10.1016/j.aap.2006.04.005
- Mezuk, B., & Rebok, G. W. (2008). Social integration and social support among older adults following driving cessation. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 63B(5), S298-S303. doi: 10.1093/geronb/63.5.S298
- Owsley, C., Stalvey, B., Wells, J., & Sloane, M. E. (1999). Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology: Medical Sciences*, 54A(4), M203-M211. doi: 10.1093/gerona/54.4.M203
- Oxley, J., & Whelan, M. (2008). It cannot be all about safety: The benefits of prolonged mobility. *Traffic Injury Prevention*, 9(4), 367-378. doi: 10.1080/15389580801895285
- Raitanen, T., Tormakangas, T., Mollenkopf, H., & Marcellini, F. (2003). Why do older drivers reduce driving? Findings from three European countries. *Transportation Research Part F: Traffic Psychology and Behaviour*, 6(2), 81-95. doi: 10.1016/S1369-8478(03)00007-X
- Rimmo, P. A., & Hakamies-Blomqvist, L. (2002). Older drivers' aberrant driving behaviour, impaired activity, and health as reasons for self-imposed driving limitations. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(1), 47-62. doi: 10.1016/S1369-8478(02)00005-0
- Ryan, G. A., Legge, M., & Rosman, D. (1998). Age related changes in driver's crash risk and crash type. *Accident Analysis and Prevention*, 30(3), 379-387. doi: 10.1016/S0001-4575(97)00098-5

- Stalvey, B. T., & Owsley, C. (2000). Self perceptions and current practices of high risk older drivers: Implications for driver safety interventions. *Journal of Health Psychology*, 5(4), 441-456. doi: 10.1177/135910530000500404
- Sullivan, K. A., Smith, S. S., Horswill, M. S., & Lurie-Beck, J. K. (2011). Older adults' safety perceptions of driving situations: Towards a new driving self-regulation scale. *Accident Analysis and Prevention*, 43(3), 1003-1009. doi: 10.1016/j.aap.2010.11.031
- Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2010). *Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010672.pdf>

Chapter 6: Study 4

The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently.

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Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2013). *The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Brisbane, Queensland. Retrieved from <http://acrs.org.au/files/arsrpe/Paper%2025%20-%20Thompson%20-%20Research%20Methods.pdf>

This study was peer-reviewed and published as part of the proceedings for the 2013 Australasian Road Safety Research, Policing and Education Conference held in Brisbane, Queensland. The author of this thesis (James Thompson) gave a 20-minute presentation of this study at the conference.

Preamble

In the literature review in Chapter 2 it was suggested that the nature of the driving environment in rural areas may both restrict the mobility of older drivers who live there and affect the risk that they are exposed to on the road. With respect to their mobility, the longer distances that need to be driven in these areas may make it more difficult to reach desired destinations, which may lead to a reluctance to make any more trips than are absolutely necessary. Furthermore, they may also prioritise their driving and, possibly, neglect activities that are discretionary in nature, such as leisure, social and community activities. In terms of risk, there are likely to be fewer intersections in rural areas, which may mean that older rural drivers are exposed to fewer potential conflict points in their driving. However, it was found in Study 2 that specific environmental variables, which were more likely to be present in the crashes of older rural drivers than older urban drivers, increased the chances that the driver would be seriously or fatally injured. Of the variables that were identified, crashing on a road with a speed limit of 100 km/h or greater produced the largest increase in the risk of serious or fatal injury to the driver. That older rural drivers were more commonly involved in crashes in areas with a speed limit of 100 km/h probably reflects the greater exposure of this group to these speeds, as they are more likely to need to drive on high-speed roads to reach their destinations. Thus, further research was needed to test these assumptions.

In order to undertake such research, detailed information relating to the driving exposure and travel patterns of older drivers from rural and urban areas was needed. In particular, information relating to the amount that they drive (kilometres, minutes, trips), the activities that they are able to undertake through their driving (both discretionary and non-discretionary), the number of intersections that they drive through (total, per distance, per time), the amount that they drive (kilometres and minutes) on roads with speed limits of 100

km/h or higher, and the amount that they travel (kilometres and minutes) at speeds of 100 km/h or faster, was required.

Driving exposure has traditionally been measured using subjective self-report measures. However, these methods tend to be inaccurate and require substantial effort for the people who volunteer for the study (Blanchard, et al., 2010; Huebner, et al., 2006; Marshall et al., 2007; Staplin, et al., 2008; Staplin, Gish, & Wagner, 2003). These methods are also restricted in the complexity of the exposure information that they are able to provide. The development of Global Positioning System (GPS) technology has offered a new alternative for accurately and objectively measuring driving exposure. However, the measurement of driving exposure using GPS technology is a relatively new practice (Stopher, FitzGerald, & Zhang, 2008) and problems relating to delayed satellite reception and insufficient power supply (both of which result in data loss) have been noted in other research (Blanchard, et al., 2010; Marshall, et al., 2007; Stopher, et al., 2008). It has also been suggested that more conventional travel survey methods work best for older participants, while GPS methods are better suited to younger participants who are more technology savvy (Bricka, Sen, Paleti, & Bhat, 2012). Moreover, some exposure information (trip purpose and driver identification) can most easily be obtained using self-report methods.

Consequently, in preparation for the final study (Study 5: Chapter 7), which compared older drivers from rural and urban areas of South Australia in terms of their driving mobility and exposure to risk, it was first necessary to evaluate whether a combination of both objective GPS-based methods and subjective self-report methods was effective as a means of measuring the driving exposure of older participants. This was the purpose of Study 4. To this end, the driving of a sample of older adults (aged ≥ 75) from rural ($N = 28$) and urban ($N = 28$) areas of South Australia (who were a sub-sample of the 170 drivers in Study 3) was monitored for one week using GPS data loggers, telephone-based travel diaries and vehicle

odometer readings. Subsequent interviews regarding the data collection process were also undertaken with a subset of 16 participants.

The first aim of this preliminary evaluation was to examine whether the data that were necessary to undertake the intended analyses for Study 5 could be obtained and whether any problems with data collection could be overcome in order to determine the viability of using these data collection methods. The second aim was to compare the distance travelled by each participant over the week as measured by GPS to that measured by the odometers in their vehicles in order to determine the accuracy of the GPS data. The third aim was to compare the trips reported daily by the participants to those recorded by GPS in order to determine the accuracy of the self-report travel diary data. The final aim was to examine the feedback that was provided by the participants who were interviewed in order to determine whether using GPS data loggers and being called daily by a researcher was acceptable to older participants.

It should be noted that the data collection and procedural evaluation was initially pilot-tested with eight participants. In this preliminary pilot-test it was found that the data collection methods were satisfactory in terms of being viable, accurate and acceptable to the eight participants and, therefore, the process was undertaken with the further 48 participants. However, although the total sample consisted of 56 older adults, the findings of only 54 participants are reported in the following paper based on this preliminary evaluation. This is because the odometer readings at the end of the week could not be collected for two participants.

**The benefits of measuring driving exposure using objective GPS-based methods and
subjective self-report methods concurrently.**

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Abstract

The measurement of individuals' driving exposure has traditionally relied on subjective self-report methods, which tend to be inaccurate and require substantial effort for the individuals volunteering for the study. Recent developments in Global Positioning System (GPS) technology have provided a new option for accurately and objectively measuring exposure. However, some exposure information (trip purpose and driver identification) is best obtained using self-report methods. The purpose of this study was to evaluate the viability and accuracy of concurrently using both GPS data loggers and travel diaries for measuring driving exposure. The driving patterns of 54 participants (aged ≥ 75) were monitored for a period of one week using GPS data loggers, telephone-based travel diaries and vehicle odometer readings. Subsequent interviews regarding the data collection process were also undertaken with a subset of 16 participants. GPS data loggers provided standard exposure measures (distance driven, time spent driving, number of trips), as well as travelling speed and driving route. The distance measured by GPS corresponded with distances obtained from the odometers, which indicated that the GPS measurements were accurate. Furthermore, the trips that were recorded by GPS were matched to the information reported in the travel diaries, enabling the purpose and driver to be identified for 95% of the trips. The participants who were interviewed provided favourable feedback regarding the data collection process. The findings indicate that GPS technology improves the measurement of driving exposure, but self-report methods are still needed to obtain certain exposure information (trip purpose and driver identification). Therefore, GPS technology complements, rather than replaces, traditional methods of measurement.

Keywords: Global Positioning Systems, travel diaries, driving exposure, travel patterns, data collection, research methods

The most common methods for measuring an individual's driving exposure have traditionally involved self-reports. However, these methods can produce inaccurate data (Blanchard, et al., 2010; Huebner, et al., 2006; Staplin, et al., 2008; Staplin, Gish, & Wagner, 2003). Self-report questionnaires, in particular, usually involve retrospective estimation of how much driving an individual has done, which may differ from the true amount due to inaccurate recall (Blanchard, et al., 2010; Huebner, et al., 2006; Staplin, et al., 2008; Staplin, et al., 2003). The difficulty of recalling prior exposure can make participants reluctant to even attempt it (Blanchard, et al., 2010).

This problem of recall bias can be reduced with the use of self-administered travel diaries, as the participant is required to actively fill out daily logs of their driving. Such methods may include a daily record of the distance travelled, as measured by the car's odometer. Travel diaries also provide a greater level of information (Blanchard, et al., 2010), such as the purpose, start/stop times and origin/destination of trips, as well as the number of trips that a driver makes. However, they require substantial effort for the study volunteers, raising the possibility that participants may forget to fill in the diary, fill it in at the last minute with incorrect information, or fail to comply; all of which result in a loss of data (Marshall et al., 2007). Older participants are also likely to find these procedures more arduous.

The development of Global Positioning System (GPS) technology has provided a new option for measuring exposure. Devices that receive GPS signals from satellites are used to provide time-stamped location information. The information is accurate to within a few metres for location and to the nearest second, or less, for time (Stopher, FitzGerald, & Zhang, 2008). When a receiver is placed in a motor vehicle, it uses the location and time information to provide an accurate measurement of the distance the car has travelled between two points, as well as the start/stop time of the trip, and the time it took the car to travel the distance. It does not rely on recall, estimations or the daily completion of detailed travel logs. Thus, the level of involvement of the participant, as well as the burden on them, is minimal.

Consequently, it provides data that is considerably more accurate and objective (Inbakaran & Kroen, 2011; Shoval et al., 2010). It has also been demonstrated, in earlier studies, that participants preferred this method to questionnaires and travel diaries (Blanchard, et al., 2010; Marshall, et al., 2007). GPS receivers that record location and time information have also proven to be small, unobtrusive, inexpensive and reliable (Duncan, Badland, & Mummerly, 2009; Shoval, et al., 2010; Stopher, et al., 2008). Moreover, recent research (Blanchard, et al., 2010; Shoval, et al., 2010) has highlighted the advantages of using this technology and shown that there are substantial discrepancies between the accurate measurements made through this method and those based on subjective self-report methods.

The application of GPS technology to measuring driving exposure further advances the detail of the exposure information that can be obtained (Marshall, et al., 2007). The combination of exact location and time information results in the ability to determine how fast a vehicle has travelled between two points, which is particularly useful for road safety research that is assessing the speeds at which people drive and whether they abide by speed limits. Furthermore, when the location and time information is imported into geographic information system (GIS) software (e.g. Google Maps or similar software), it provides a way of visualising where the driving took place. This allows examination of the characteristics of the roads on which the driving occurred (e.g. number of intersections, lanes, etc.), as well as the routes that people have taken to reach their destinations (Marshall, et al., 2007).

One disadvantage of data collection using GPS devices is that the reduced involvement of the participants does result in an inability to obtain some important information from the GPS receivers alone. This includes determining the purpose(s) behind individual driving trips (e.g. shopping) and identifying the driver of the vehicle (necessary when the participant's vehicle is also driven by one or more other drivers).

As preparation for a study using GPS-based measurements of driving exposure and travel patterns to compare older drivers (aged 75 years and older) from rural and urban areas

of South Australia in terms of their driving mobility and safety, it was first necessary to evaluate the process of using GPS receivers for data measurement with older road users. It has previously been argued that more traditional travel survey methods work best for older travellers, while GPS methods are better suited to younger study participants who are more technology savvy (Bricka, Sen, Paleti, & Bhat, 2012). A sample of 54 older drivers were recruited for the study and had a GPS device installed in their vehicle for a week to measure their driving.

Participants were phoned by the lead researcher (JPT) on a daily basis during the one-week testing period and asked to provide the purpose and who was driving the vehicle for each trip. This method was similar to that of a conventional travel diary, but was intended to be less strenuous for the participant because the researcher would record the information; hopefully reducing non-compliance and data loss. It was thought that, through the combination of daily phone calls and GPS receivers, all necessary information could be measured and the limitations of each separate method could be overcome.

Previous studies have compared self-report and GPS-based methods of data collection (Blanchard, et al., 2010; Bricka, et al., 2012; Huebner, et al., 2006; Marshall, et al., 2007). For example, Bricka et al. (2012) used self-report travel diaries and GPS devices to monitor the travel patterns of participants aged 16 years and older over a 24-hour period. It was found that both methods demonstrated a degree of data loss (i.e. trips that were not reported or recorded), but that each method was helpful in identifying the instances of missed data in the other method. As a result, it was concluded that, rather than GPS methods replacing traditional self-report methods, both methods should be used in combination. Blanchard et al. (2010) used in-vehicle recording devices (with GPS), questionnaires, trip logs, activity diaries, and follow-up interviews to monitor the driving exposure and patterns of older drivers (aged 67 years and older) over a period of one week. It was found that self-estimates of distance-driven over the week were inaccurate and were often not attempted by the participants. In addition, a

significant number of trips were missed in the diaries. However, the self-report methods were needed in order to obtain the full range of important information (i.e. trip purpose, driver identification) and, therefore, using both objective and self-report methods together was seen as the best way to measure driving exposure and travel patterns. Building on these past studies, the purpose of the present study was to evaluate a particular GPS device (called a Trip Recorder) and develop the method of phoning the participants daily in order to obtain the necessary self-report data. To the best of the knowledge of the authors, such a telephone-based self-report method has not been used in previous research.

The first aim of this preliminary evaluation was to examine whether any problems with data collection, as noted by the researcher, could be overcome in order to determine the viability of using both GPS receivers (also referred to as GPS data loggers) and the process of phoning the participants daily to collect data. The second aim was to compare the distance travelled by each participant over the week as measured by GPS to that measured by the odometers in their vehicles in order to determine the accuracy of the GPS data. The third aim was to compare the trips reported daily by the participants to those recorded by GPS in order to determine the accuracy of the self-report travel diary data. The final aim was to examine the feedback that was provided by the participants who were interviewed in order to determine whether using GPS data loggers and being called daily by a researcher was acceptable to older participants.

Method

Participants

Participants for both the present study and the subsequent study were recruited at the South Australian Royal Automobile Association's (RAA) "Years Ahead" presentations. The RAA is an independent automobile club in SA that provides services such as 24-hour

emergency breakdown assistance, insurance and road safety information to the approximately 560,000 members. The “Years Ahead” presentations are held at senior citizens clubs and churches throughout SA and provide information on road safety specifically focusing on older adults. One of the researchers (JPT) spoke about the study at these presentations and invited attendees to participate.

Participants had to be aged 75 years or older, hold a valid driver’s licence for a car (class C licence, entitling a person to drive non-commercial motor vehicles not exceeding 4,500kg), have driven at least once in the previous month, and speak fluent English. The total sample consisted of 54 older drivers (23 females, 31 males), with 27 participants from metropolitan Adelaide (13 females, 14 males) and 27 from rural areas beyond metropolitan Adelaide (10 females, 17 males). Participants ranged in age from 75 to 90 years, with a mean of 80.3 ($SD = 3.7$). Urban participants had a mean age of 80.6 years ($SD = 3.6$) and rural participants 79.9 years ($SD = 3.8$). Participants were entered into a draw to win one of five \$50 gift-vouchers to thank them for their assistance.

Materials

The cognitive functioning of each participant was assessed prior to their involvement in the study in order to screen for cognitive decline and ensure that they had the ability to recall specific information about their driving. The Mini-Mental State Examination, 2nd edition (MMSE-2) (Folstein, Folstein, White, & Messer, 2010) was used for this purpose. Scores can range from 0 to 30, with higher scores indicating higher levels of cognitive functioning. Participants were excluded if they scored 24 or less, as this cut-off is thought to be suggestive of cognitive impairment (Lezak, Howieson, Bigler, & Tranel, 2012). No participant scored ≤ 24 on this measure (mean = 28.56, $SD = 1.27$), consequently no-one was excluded from the research.

The GPS data logger that was used was the 747ProS GPS Trip Recorder (TranSystem Inc., Hsinchu, Taiwan). Figure 1 displays a digital photograph of the device (hereafter referred to as Trip Recorder). This data logger was selected for several reasons. Firstly, it is small (width = 47mm, length = 72 mm, height = 20 mm, weight = 65gm) and can be mounted onto the vehicle's dashboard. It has 64Mb of internal memory and can be set to record location and time information by specified time intervals, distances or speeds. For this study, it was set to record data every second. Depending on the strength of the satellite reception (which can be affected by overhanging trees, tall buildings, inclement weather, tunnels, etc.), the accuracy of the information that the Trip Recorder records is within 3 metres, for location, and to the nearest second or less, for time. This level of accuracy corresponds with other contemporary GPS data loggers (Stopher, et al., 2008).



Figure 1. Digital photograph of the 747ProS GPS Trip Recorder shown with the car charger.

The Trip Recorder has a rechargeable battery, which provides 30 hours of operation time and 300 hours of standby time. When attached to the vehicle's AC power using a car charger, however, it has a setting that synchronises its operation with the vehicle's ignition.

Thus, it only records data when the ignition is on and the device is receiving power; when the ignition is off, it goes into standby mode. This reduces the consumption of the internal battery power, as well as continually recharging it. It also groups the data into separate ‘trips’ - a section of driving in which the vehicle was started at a certain location, driven and then stopped at a particular destination - because it starts recording when the vehicle is started and driven, and then stops when the vehicle is turned off. Moreover, by not operating continuously, it eliminates needless data. It also has a built-in motion sensor. When it is set to use this sensor, it will start recording data when motion is detected (i.e. when the car is in motion) and will enter standby mode when it is static for two minutes. This was useful for vehicles in which the AC connection was not working or was used for another purpose (e.g. charging a mobile phone). Use of this sensor prolongs the life of the internal battery and, as with the car charger, eliminates needless data and separates trips.

The Trip Recorder obtains and records data independently of the vehicle it is placed in. This differs from other data loggers which connect to the vehicle’s on-board computer and only work in cars manufactured after 1996 (Blanchard, et al., 2010; Huebner, et al., 2006; Marshall, et al., 2007). Unlike these loggers, the Trip Recorder also works in hybrid cars that switch between power sources.

A common problem with the use of GPS data loggers relates to ‘cold starts’ (Blanchard, et al., 2010; Stopher, et al., 2008). These occur at the beginning of trips when the device is delayed in acquiring adequate satellite reception. The vehicle may travel a distance before a signal is acquired. This can result in the device not logging the start of a trip or, if the trip is short, the entire trip. If the device is stationary during this process it may obtain reception relatively quickly, if it is already in motion, however, it may take longer. The time by which data recording is delayed, due to cold starts, is continually being reduced as the reception acquisition rates of newer GPS receivers improve. The Trip Recorder has an average acquisition rate of 35 seconds for cold starts when the device is switched on for the

first time, which is similar to other contemporary devices. It has several advantages, however. Firstly, when the vehicle is stopped the Trip Recorder does not turn off but goes into standby mode. When started from standby, it reacquires reception faster (one second or less). It also has the ability to use assisted GPS (A-GPS) information, which is downloaded from the satellite network. This information relates to the orbital location of satellites and helps the device locate satellites faster, thereby reducing the time that it takes to receive data.

A computer program that was supplied with the Trip Recorder, called GPS Photo Tagger, was used to change the settings on the device, import the A-GPS information, and retrieve the recorded GPS data. The retrieved data was then imported into a program that was developed by the researchers at the Centre for Automotive Safety Research (University of Adelaide) for analysis. The program organises the data for each participant into a list of separate trips. The information that is provided for each trip includes the date and time when it started, the distance (kilometres) and duration (minutes), and the average, minimum and maximum speeds (km/hour). The total kilometres and minutes, as well as the average speed, over all of the combined trips, are also displayed. Each trip can be viewed on a map, with a line representing the trip from start to finish. Along this line are dots for each instance where the location and time are recorded, which occur every second. The dots and line are coloured differently according to the speed at which the vehicle is travelling at the time, with different colours representing 0 to 59 km/h, 60 to 79 km/h, 80 to 99 km/h and 100 km/h and over. The researcher can select a segment of a trip by clicking on any two dots on a line, which then displays the distance (metres) between the two points and the time (seconds) that the vehicle took to travel between them. This option allows the researcher to highlight a segment where, for example, the participant was travelling over 100km/h.

A ‘Travel Diary’¹¹ was used by the researcher when contacting the participants on a daily basis to record the details of all of the driving that occurred in the vehicle(s) in which a

¹¹ A copy of the Travel Diary is provided in Appendix D.

Trip Recorder had been installed. The Travel Diary was used to record the date, the driver, start location and destination, trip purpose (e.g. shopping), and approximate start and end times of each trip. Odometer readings for the participants' vehicles were also recorded at the beginning and end of the week.

Feedback¹² was also sought from a subset of the participants ($n = 16$) in terms of whether they found taking part in the study easy, whether they were bothered by being called each day about their driving, whether they were bothered by having a GPS device in their car, and whether the GPS affected their normal process of driving. Each of these items was rated on a four-point scale (1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree). They were also asked whether they changed their normal driving routines because they had a GPS in the car and whether they forgot about the presence of the GPS. Each of these items was rated on a three-point scale (1 = not at all, 2 = somewhat, 3 = greatly).

Procedure

Following recruitment, the researcher (JPT) visited the home of each participant to obtain written consent for participation¹³, administer the MMSE-2, and install the Trip Recorder into the participant's vehicle. If they drove more than one vehicle, a device was placed in each. If the AC power connection in the vehicle was not working, or if it was needed for another purpose, the device was set to use the motion sensor. The researcher also recorded the vehicle's odometer reading.

The researcher telephoned participants on a daily basis during the week to record the Travel Diary information and returned to their residence at the completion of the seven day period. On this second visit, the researcher recorded the final information for the Travel

¹² A copy of the feedback sheet is provided in Appendix E.

¹³ Copies of the information sheet and the consent form for the cognitive screening, Travel Diary and GPS tracking section of this research are provided in Appendices F and G.

Diary, removed the Trip Recorder and took a final odometer reading. In addition, 16 participants provided feedback on the study.

The Trip Recorder data for each participant was imported to the computer program that was developed specifically to analyse it. Trips were excluded if the motion sensor was activated and the distance travelled was 0.00, 0.01 or 0.02 km. These recordings resulted from the sensor being highly sensitive to movement, such that a car would be turned off and stationary but something (e.g. passing truck) would cause the Trip Recorder to sense motion and start recording for at least two minutes until it returned to standby mode. The trips with a recorded distance of 0.01 and 0.02 km (i.e. 10 and 20 metres) resulted from longer periods of motion-induced data recording, where random minor errors in the GPS location were erroneously recorded as distance travelled by the vehicle.

Results and Discussion

The evaluation of both the Trip Recorder and the Travel Diary as means of measuring driving exposure among a sample of older adults can be summarised in terms of any problems with data collection that were noted by the researcher, the correspondence between distances measured by the GPS and vehicle odometer, correspondence between individual driving trips recorded by GPS and those reported by the participants, and participant feedback.

Problems with data collection

Several problems were noted by the researcher when using the Trip Recorder to measure driving exposure. Firstly, the AC power was not working in several vehicles and, consequently, the motion sensor was used. However, although the motion sensor prolongs the life of the internal battery (by returning to standby when no motion is detected), it does not have enough power to run the Trip Recorder for an entire week. Therefore, the researcher had

to return to the residence of each of these participants mid-week to exchange the first device with a fully charged device in order to address this issue.

Secondly, there were several instances where the Trip Recorder was delayed in acquiring satellite reception at the start of a trip. This was evident when the trip was viewed on the map and there were scattered data points at the start which were a distance away from where the previous trip ended. In these cases, adequate reception was quickly obtained and the remainder of the trip was recorded, but the data for the beginning of the trip was not useable. It was unclear what caused this. It was not due to a cold start because the vehicle was stationary for a short period and the device was in standby and using A-GPS information. The most likely explanation was that there were buildings or trees that were blocking adequate reception. There were also three instances where a trip was not recorded at all. These instances were evident when the GPS data was matched to the information reported in the Travel Diaries. In two instances, the participants reported making a trip to a particular destination and then returning home, however, the trip to the destination was not recorded by the Trip Recorder in one instance and the return trip home was not recorded in the other instance. In the third instance, two consecutive trips were missing (i.e. the participant reported driving to the hairdresser and home again, however, neither trip was recorded). It was unclear why these instances occurred. It is possible that the Trip Recorder was unable to acquire adequate reception at any point during the trips. In the case of the two consecutive missing trips, it is possible that the participant mistakenly reported an outing that did not occur rather than an error by the Trip Recorder. While all participants were screened for cognitive impairment, using the MMSE-2, it is possible that these trips were mistakenly recalled. Importantly, these were only four trips relative to 1,218 trips successfully recorded by the Trip Recorder for all of the participants.

Correspondence between distance measured by vehicle odometers and GPS

The difference between the vehicle odometer and Trip Recorder measurements of total distance (km) travelled over the week was calculated for each participant. The Trip Recorder yielded a smaller measurement than the odometer for 38 of the 54 participants (70%) and a larger measurement for the other 16 (30%). The difference was less than one kilometre for 24 (44%) participants, which is small and may be accounted for by the fact that the odometer measurements were recorded in whole kilometres. However, the data for 23 participants (43%) showed differences that were between 1 and 5 kilometres and 7 (13%) were between 5 and 9 kilometres. It should be noted, though, that some participants travelled much further over the week than others (odometer measurements ranged from 5 to 554 km). Thus, a difference between 5 and 9 kilometres is relatively small for a participant who travelled a large total distance. Consequently, the difference between the odometer and GPS measurements as a proportion of total distance (measured by odometer) was calculated for each participant (displayed in Figure 2). The differences represented less than 4% of the total distances of 47 (87%) of the participants, but were larger for the others. The highest proportional difference was 15%, where the odometer measurement was 45 km and the GPS was 38.43 km. However, this was the case where the Trip Recorder failed to record the participant's trips to the hairdresser and home again, which may explain the large difference. In addition, the third largest proportional difference (9%), was for one of the other two participants for whom a trip was not recorded.

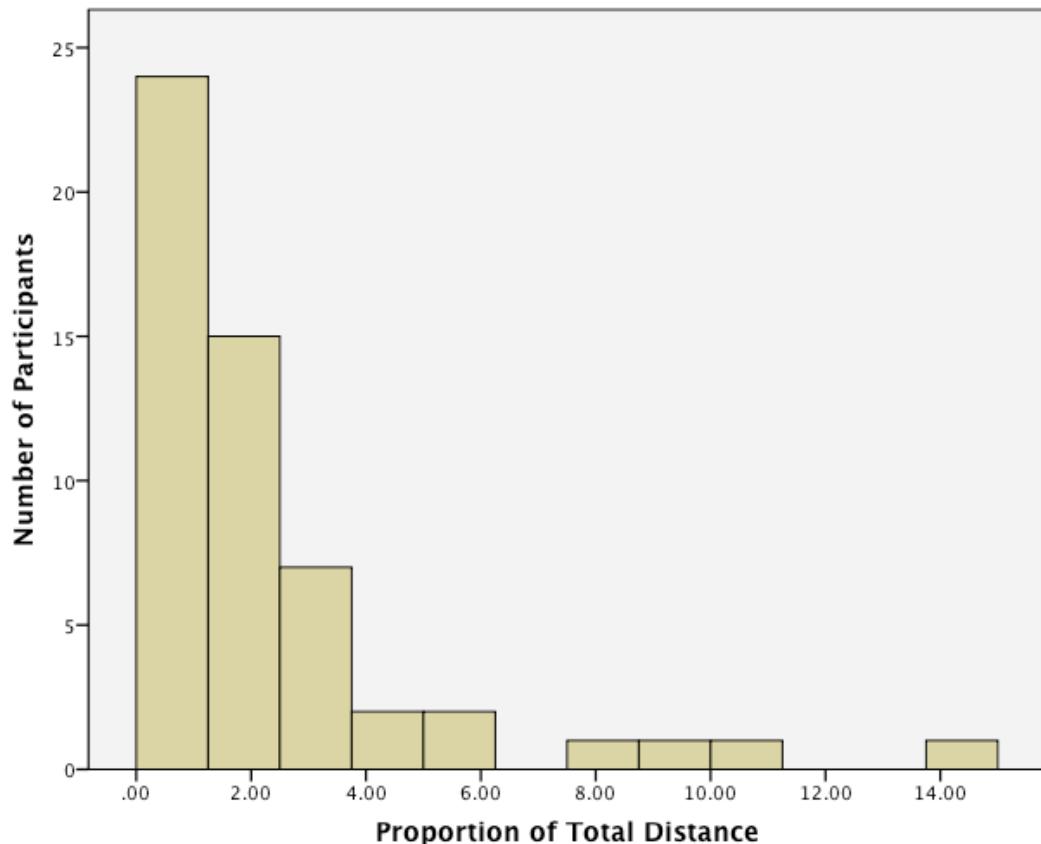


Figure 2. The proportional difference between odometer and Trip Recorder measurements of total distance travelled over one week for each participant.

Correspondence between the trips recorded by GPS and those reported by the participants

Of the 1,218 trips recorded by the Trip Recorder for all of the participants, 1,005 (82%) were reported by the participants in their Travel Diaries. Thus, the purposes for these trips could be identified. The purposes of a further 154 (13%) were identified by the researcher in several ways. Firstly, a vehicle may have been re-parked or moved in/out of the garage, which could be identified on the map display. Sometimes a participant would forget to report that they made an extra stop at home before their next trip - this, too, could be detected on the map. An unreported trip often had the same destination (and purpose) as other trips made during the week (e.g. supermarket), which could also be detected on the map. The location where a trip ended could additionally be viewed through Street View in the Google Maps internet site (<http://maps.google.com/>). By doing so, the researcher could often determine the most likely purpose of the trip (e.g. library, shopping centre), although it is

possible that the true purpose would not be identified using this method (e.g. driving to a shopping centre to go to the bank). Of the total 1,218 trips, there were 59 (5%) that were not reported and for which their purpose could not be identified.

A total of 13 participants shared the driving of the vehicle in which the Trip Recorder was installed with another driver. This other driver was often a spouse, who only drove occasionally. The participant's driving was easily differentiated from the other driver's using the Travel Diary information. The driver of any unreported trips was also identifiable because such trips usually occurred as one in a group of trips made by a particular driver. For example, the participant might travel from home to the bank, to the petrol station, to the supermarket, and then home again, but would forget to report their stop at the petrol station. It was assumed that the same driver made all of these trips.

Participant feedback

The participants' responses to the four feedback statements are displayed in Table 1. All either "strongly agreed" or "agreed" that: participation in this study was easy, they were not bothered by being phoned each day and having to report their driving, they were not bothered by having the GPS device in their cars, and the GPS device did not affect the normal process of driving their car. This indicates that the participants viewed the data collection process favourably.

Table 1
Participants' Responses (Number of Participants) to the Feedback Statements

	Strongly agree	Agree	Disagree	Strongly disagree
I found that taking part in this study was easy.	11	5	0	0
I was not bothered by being called up each day and having to report my driving.	13	3	0	0
I was not bothered by having the GPS device in my car.	13	3	0	0
The GPS device did not affect the normal process of driving my car.	14	2	0	0

The responses to the remaining two feedback questions are displayed in Table 2. All of the participants reported that they did not change their normal driving routines in any way because they knew that the GPS device was in their cars. In contrast, responses to the second question varied, but most participants reported that they “greatly” or “somewhat” tended to forget that the GPS device was in their cars while they were driving. These responses suggest that the participants and their driving routines were not affected by an awareness of the Trip Recorder in their vehicles.

Table 2

Participants' Responses (Number of Participants) to the Feedback Questions

	Not at all	Somewhat	Greatly
Did you change your normal driving routines in any way because you knew that the GPS device was in your car?	16	0	0
While you were driving, did you tend to forget that the GPS device was in your car?	3	8	5

Discussion

The purpose of this study was to evaluate the use of a particular GPS data logger, called a Trip Recorder, as a means of measuring driving exposure for a subsequent study focusing on the driving mobility and safety of persons aged 75 years and older. The Trip Recorder was able to provide standard exposure measures for all participants, such as distance driven, time spent driving and number of trips, as well as the start and stop times and dates of trips. It also provided more complex measures, such as travelling speed. When the data were examined with mapping software that was specifically developed for this research, the origin and destination of trips, and information relating to the roads and routes on which the driving occurred, could also be obtained.

Information relating to trip purpose and driver identification was also necessary, but is not obtainable through the use of GPS data loggers alone (Blanchard, et al., 2010). It can be obtained using travel diaries, but their use is limited by the burden it places on participants

and the likelihood that they will forget to fill in the diary, or fill it in with incorrect information. Consequently, a further objective was to develop and evaluate a procedure for contacting the participants on a daily basis during the testing period in order to record this information. It was hoped that this would overcome the limitations of conventional travel diaries, while still providing information relating to trip purpose and driver identification. The necessary information was easily obtained with this method. Furthermore, the information was easily matched to the trips recorded on the Trip Recorder. Thus, in combination, the Trip Recorder and daily calls to participants provided the necessary data to complete the analyses for the next study. Blanchard et al. (2010) and Bricka et al. (2012) also agree that a combination of electronic and self-report methods are necessary to obtain the full range of exposure data. Moreover, an additional benefit of the Travel Diary in the present study was that the information that was reported by the participants was used to identify instances where the GPS device may have failed to record data. This demonstrates that, as was also concluded by Blanchard et al. (2010) and Bricka et al. (2012), GPS may not completely replace traditional methods of measuring driving exposure, but complement them.

Other driver identification methods have been proposed, including key fobs or entry codes that are required when starting the car (Blanchard, et al., 2010; Marshall, et al., 2007), which inform the data logger who the driver is. These may work with research where only data loggers are used, but where some form of participant self-report is necessary to determine trip purpose as was the case here, an extra question on driver identification is a simpler option. Another option would be to use wearable devices (Stopher, et al., 2008) or applications downloaded onto mobile phones (Inbakaran & Kroen, 2011), where the participant carries the device on them instead of it being installed in their vehicle. Thus, only the participant's travel is recorded. However, wearable GPS devices rely on battery power, which limits the period of data collection. Both of these alternatives also require the participant to remember to carry the device or phone, which means increased involvement and

awareness of the process from the participant. There is also the additional difficulty of differentiating between different modes of travel (e.g. public transport) and when the participant is a passenger, rather than the driver.

In the present study, it was the researcher who filled out the Travel Diary. The participant was only required to recall what driving they had done the previous day. In addition, the participants reported that they were not bothered by being called up each day and having to report their driving. This suggests that this method does not cause undue inconvenience for the participants and is acceptable to them.

As the demands and inconvenience of the Travel Diary are minimal, it was expected that there would be a high level of compliance by the participants and minimal missing data. All of the participants reported their daily driving. When the trips that they self-reported were matched to those recorded by the Trip Recorder, it was found that the majority were reported. The purpose and driver of the majority of those that were not reported, could be identified by the researcher using the map display. The daily contact with the researcher is likely to have reduced the data loss because it is likely to have encouraged diligence by the participants, as they could not leave it to the end of the week to report all of their driving. Therefore, this process appears to overcome many of the limitations of conventional travel diaries, where the participant is required to record the necessary information.

The accuracy of the GPS measurements of distance were also demonstrated. The measurements were found to correspond with the distances recorded by the participants' vehicle odometers. Indeed, for a majority (87%) of the participants, the difference between the measurements represented less than 4% of their total travel distance over the week. This is consistent with research by Huebner et al. (2006) who compared GPS measurements over a 26 km road course to those made by a CarChip device (which plugs into the vehicle's on-board computer to obtain exposure information) and found that the mean difference between measurements was less than 1%.

Furthermore, the process of using the Trip Recorder was found to be favourable and undemanding for the participants, as they reported that they were not bothered by having it in their cars, it did not affect the normal process of their driving, they tended to forget that it was present, and they did not change their normal driving routines in any way because of the GPS. This corresponds with similar research by Blanchard et al. (2010) who found that their participants reported that the GPS devices were barely noticeable and did not affect their driving behaviour.

Several problems with the Trip Recorder were noted, but were able to be addressed so that they did not impede the data collection. There were some problems relating to delayed reception and power supply, but these are not unique to the Trip Recorder and have been noted in research using other GPS devices (Blanchard, et al., 2010; Marshall, et al., 2007; Stopher, et al., 2008). The use of GPS data loggers to measure driving exposure is still in its early stages, but does have a number of advantages. Furthermore, there is likely to be continual improvement as the techniques, technology and general knowledge regarding the application of this technology develop. In addition, the daily contact with the participants in this study holds potential for providing useful information, without being intrusive. It should be noted, however, that while daily calls were feasible for a sample of 54 participants, this would be more difficult to manage if the sample size was considerably larger. It may also be more difficult with other age groups for various reasons (e.g. work/social commitments).

In the following study, these measurements of driving exposure are used to compare the rural and urban older participants in terms of their everyday driving mobility (i.e. number of trips for discretionary/non-discretionary purposes) and safety (i.e. number of intersections driven through and amount of driving on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster). However, many other issues can be examined using the present data collection methods. For example, Blanchard et al. (2010) compared the GPS and travel diary measurements of the driving exposure and travel patterns of older adults

in order to demonstrate that they avoid challenging driving situations (i.e. self-regulate their driving) less than they report. Research by Marshall et al. (2007) has also demonstrated that the braking and acceleration patterns of older adults can be examined using GPS. Similarly, Meredith et al. (2013) used GPS devices with in-built accelerometers to identify rapid deceleration events in the driving of older adults and to obtain information about the context of these events (i.e. location, time of day, speeds before and after, duration of deceleration). Additionally, other information could be obtained through the telephone-based Travel Diary, such as participant reports of the number of passengers in their vehicle or the weather conditions at the time of their driving. Such examinations will build on our understanding of the driving exposure of older adults.

References

- Blanchard, R. A., Myers, A. M., & Porter, M. M. (2010). Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. *Accident Analysis and Prevention*, 42(2), 523-529. doi: 10.1016/j.aap.2009.09.018
- Bricka, S. G., Sen, S., Paleti, R., & Bhat, C. R. (2012). An analysis of the factors influencing differences in survey-reported and GPS-recorded trips. *Transportation Research Part C*, 21, 67-88. doi: 10.1016/j.trc.2011.09.005
- Duncan, M. J., Badland, H. M., & Mummary, W. K. (2009). Applying GPS to enhance understanding of transport-related physical activity. *Journal of Science and Medicine in Sport*, 12(5), 549-556. doi: 10.1016/j.jsams.2008.10.010
- Folstein, M. F., Folstein, S. E., White, T., & Messer, M. A. (2010). *MMSE-2: Mini-Mental State Examination, 2nd edition*. Lutz, Florida: PAR.
- Huebner, K. D., Porter, M. M., & Marshall, S. C. (2006). Validation of an electronic device for measuring driving exposure. *Traffic Injury Prevention*, 7(1), 76-80. doi: 10.1080/15389580500413067
- Inbakaran, C., & Kroen, A. (2011). *Travel surveys – Review of international survey methods*. Paper presented at the 34th Australasian Transport Research Forum, Adelaide, South Australia. Retrieved from <http://casr.adelaide.edu.au/dbtw-wpd/Textbase/Catalogue/Conf/ATRF2011/Inbakaran.pdf>
- Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological assessment* (3rd ed. ed.). New York: Oxford University Press.
- Marshall, S. C., Wilson, K. G., Molnar, F. J., Man-Son-Hing, M., Stiell, I., & Porter, M. M. (2007). Measurement of driving patterns of older adults using data logging devices with and without global positioning system capability. *Traffic Injury Prevention*, 8(3), 260-266. doi: 10.1080/15389580701281792

- Meredith, L., Brown, J., Clarke, E., Coxon, K., Boufous, S., Ivers, R., & Keay, L. (2013). Validation of an in-vehicle monitoring device for measuring driving exposure and deceleration events. *Journal of the Australasian College of Road Safety*, 24(1), 42-50. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRSjournalVol24No1Feb13WEBv2.pdf>
- Shoval, N., Auslander, G., Cohen-Shalom, K., Isaacson, M., Landau, R., & Heinik, J. (2010). What can we learn about the mobility of the elderly in the GPS era? *Journal of Transport Geography*, 18(5), 603-612. doi: 10.1016/j.jtrangeo.2010.03.012
- Staplin, L., Gish, K. W., & Joyce, J. (2008). 'Low mileage bias' and related policy implications - A cautionary note. *Accident Analysis and Prevention*, 40, 1249-1252. doi: 10.1016/j.aap.2007.10.012
- Staplin, L., Gish, K. W., & Wagner, E. K. (2003). MaryPODS revisited: Updated crash analysis and implications for screening program implementation. *Journal of Safety Research*, 34(4), 389-397. doi: 10.1016/j.jsr.2003.09.002
- Stopher, P., FitzGerald, C., & Zhang, J. (2008). Search for a global positioning system device to measure person travel. *Transportation Research Part C*, 16(3), 350-369. doi: 10.1016/j.trc.2007.10.002

Chapter 7: Study 5

A GPS-based examination of the mobility and exposure to risk of older drivers from rural and urban areas

This chapter consists of a paper submitted to the Journal of the Australasian College of Road Safety for publication. The details of this submission are:

Thompson, J.P., Baldock, M.R.J., Mathias, J.L., & Wundersitz, L.N. (2014). *A GPS-based examination of the mobility and exposure to risk of older drivers from rural and urban areas*. Manuscript submitted for publication.

Preamble

Following on from the data collection and preliminary procedural evaluation that formed the basis of Study 4, the driving exposure and travel pattern information that was collected with the older participants (aged ≥ 75) from rural ($N = 28$) and urban ($N = 28$) areas of South Australia was used in the final study in this research (Study 5). The purpose of Study 5 was to examine whether older rural drivers, when compared to older urban drivers, are more restricted in their everyday driving mobility (access to discretionary and non-discretionary lifestyle activities), and differ in their exposure to risk while driving (exposure to potential conflict points and high-speed driving environments). The rural and urban participants were compared in terms of the amount that they drove over the period of one week, the activities that they undertook through their driving, and their exposure to both intersections (potential conflict points) and high-speed driving conditions. It was hypothesised that older rural drivers would drive longer distances than older urban drivers, but would be more restricted in their everyday driving mobility, making fewer trips and undertaking fewer discretionary activities. It was also hypothesised that older rural drivers would have a lower exposure to intersections (total intersections, intersections per distance, per time), but a higher exposure to high-speed driving environments (driving further and for longer periods on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster) than older urban drivers.

**A GPS-based examination of the mobility and exposure to risk of older drivers from
rural and urban areas.**

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The authors would like to express their gratitude to the following people from the Centre for Automotive Safety Research: Craig Kloeden for developing the GPS data analysis program and Stephen Crotty for assisting in the GPS data analysis.

Abstract

This study examines whether older rural drivers are restricted in their driving mobility and are exposed to more risk when driving than older urban drivers. Participants (aged ≥ 75 years) from rural ($n = 28$) and urban ($n = 28$) areas of South Australia were monitored using GPS devices and telephone-based travel diaries. The rural and urban participants did not differ in the number of trips that they made for discretionary or non-discretionary activities. However, while rural participants were exposed to fewer intersections (potential conflict points) in their driving than urban older drivers, they drove further and for longer periods on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster. Therefore, they are not less mobile but have a higher exposure to road conditions that are more likely to lead to serious and fatal injuries in a crash.

Keywords: older drivers, rural areas, GPS, public health, road safety, driving mobility

Driving enables older adults to remain mobile, which is important for their independence and lifestyle (Adler, Rottunda, & Kuskowski, 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Marottoli et al., 2000; Whitehead, Howie, & Lovell, 2006). Moreover, a loss of mobility through driving cessation can lead to depression (Fonda, Wallace, & Herzog, 2001; Marottoli et al., 1997), a reduced network of friends (Mezuk & Rebok, 2008), and an increased risk of mortality over a 3-year period (Edwards, Perkins, Ross, & Reynolds, 2009). While mobility is desirable, it has also been found that older drivers have a higher crash rate per distance driven and an increased risk of being seriously or fatally injured (Baldock & McLean, 2005; Hanrahan, Layde, Zhu, Guse, & Hargarten, 2009; Kahane, 2013; Meulenens, Harding, Lee, & Legge, 2006; Rakotonirainy, Steinhardt, Delhomme, Darvell, & Schramm, 2012; Ryan, Legge, & Rosman, 1998; Thompson, Baldock, Mathias, & Wundersitz, 2010). It is thought that this increased risk of injury results from greater fragility, such that older people have a lower tolerance to physical trauma than younger persons (Li, Braver, & Chen, 2003; Viano, Culver, Evans, & Frick, 1990). Consequently, the focus of recent research has been on maintaining an optimal level of mobility for older drivers, while also reducing their exposure to risk when on the road (Baldock, Mathias, McLean, & Berndt, 2006; Berry, 2011; Marottoli & Coughlin, 2011; Oxley & Whelan, 2008).

Older drivers who live in rural or remote areas are of particular interest because the nature of their driving environments may both restrict their mobility and increase their risk on the road. Firstly, in terms of mobility, the longer distances that need to be driven in these areas may reduce the ease with which drivers are able to reach their destinations, which may make them reluctant to make any more trips than are absolutely necessary. Hough, Cao and Handy (2008) examined the travel patterns of elderly women in rural areas of North Dakota, USA, and found that they tended to make fewer trips than older women living in small urban areas. However, there may be more to a person's mobility than just the number of outings that they undertake. Indeed, Nordbakke (2013) defines mobility as "the ability to choose where

and when to travel and which activities to participate in outside the home in everyday life” (p.166). Mobility may be restricted for rural residents because they may have to prioritise their driving and neglect discretionary activities (e.g., social activities). Consistent with this, Hough et al. (2008) found that rural older women travel less often than older women from small urban areas particularly for certain activities, such as going to a restaurant, friend’s house, store, hair salon, or place to exercise. Thus, older rural drivers may do more driving because of the distances they need to travel, but their mobility may be restricted, which may affect their quality of life.

In terms of risk, the high crash rate per distance driven of older drivers may result from the fact that they travel smaller distances, on average, than younger drivers (Baldock & McLean, 2005; Li, et al., 2003; Ryan, et al., 1998) and may therefore undertake most of their driving on local roads with more potential crash points (e.g., intersections) (Hakamies-Blomqvist, Raitanen, & O'Neill, 2002; Janke, 1991; Langford, Methorst, & Hakamies-Blomqvist, 2006). In contrast, drivers who travel large distances may do much of their driving on high-speed freeways, where there are fewer potential conflict points and crashes are rare per unit-distance. Indeed, an increased crash rate per distance driven has been shown to be the case for drivers who travel fewer kilometres, regardless of their age, and is termed the “low mileage bias” (Hakamies-Blomqvist et al., 2002; Janke, 1991; Langford, 2009; Langford et al., 2006). Low mileage bias has implications for understanding the safety of older rural drivers because they may travel longer distances than older urban drivers and undertake more driving on high-speed rural freeways, which would be expected to reduce their crash rate per kilometre driven. However, when Hanson and Hildebrand (2011) measured the exposure of older rural drivers to rural and urban roads, using both Global Positioning Systems (GPS) and self-report methods, they found that the proportion of travel on urban streets increased with self-reported mileage and decreased with age. This study also provided crash data, which indicated that rural drivers aged 81 and over had a higher crash rate per kilometre driven than

their urban counterparts. As a result, they suggested that low mileage bias may not exist for older drivers in the rural context. In their analyses, Hanson and Hildebrand did not examine the exposure of older rural drivers to potential conflict points (intersections) compared to older urban drivers. Such an examination could be important, given that the reason proposed by Janke (1991) for a reduction in crashes per distance driven for high mileage drivers was that they frequently use high-speed freeways with relatively few conflict points.

Other research has compared the rates of serious and fatal injuries in older drivers (\geq 75 years) and found that rural drivers are more than twice as likely to be seriously or fatally injured than urban drivers when involved in a crash (Thompson, et al., 2010). Subsequent research by Thompson, Baldock, Mathias, and Wundersitz (2013c) established that certain environmental variables, which were more likely to be present in the crashes of older rural drivers, increased the chances that the driver would be seriously or fatally injured. More specifically, the greatest risk of a serious or fatal injury to older drivers was having a crash on a road with a speed limit of 100 km/h or greater. That rural drivers were more likely to be involved in crashes on these high-speed roads probably reflects the greater exposure of this group to these roads. Therefore, while Hanson and Hildebrand (2011) examined the exposure of older rural drivers to high-speed roads in relation to the risk of crash involvement, they did not examine their exposure to these roads in terms of their increased risk of serious or fatal injury in the event of a crash. They also did not directly compare the exposure of older rural drivers to these roads with that of older urban drivers.

Thus, overall, the aim of the present study was to examine whether older rural drivers are more restricted in their everyday driving mobility and whether they have a higher level of exposure to risk while driving, compared to older urban drivers. The driving exposure and travel patterns of both groups were monitored for a period of one week using GPS data loggers and travel diaries. The groups were compared in terms of the amount that they drove over a one-week period, the activities that they undertook through their driving, and their

exposure to both intersections (potential conflict points) and high-speed driving conditions. The age of their vehicles was also compared in order to determine whether the safety of their vehicles differed, because it has been shown that newer vehicles provide superior protection from serious or fatal injury in the event of a crash (Anderson & Doecke, 2010; Anderson & Hutchinson, 2010; Newstead, Watson, & Cameron, 2008; Ryb, Dischinger, & Ho, 2009).

It was hypothesised that (1) older rural drivers would drive longer distances than older urban drivers, but would be more restricted in their everyday driving mobility, making fewer trips and undertaking fewer discretionary activities. It was also hypothesised that (2) older rural drivers would have a lower exposure to intersections (total intersections, intersections per distance, per time), but a higher exposure to high-speed driving environments, driving further and for longer periods on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster.

Method

Participants

Participants were recruited from groups of older adults who attended road safety presentations given by the South Australian Royal Automobile Association, which is an independent automobile club (approximately 560,000 members). The presentations, entitled “Years Ahead”, were held at churches and senior citizen’s organisations in rural and urban areas of SA. One of the researchers (JPT) spoke at these presentations and invited attendees to participate in the research.

Participants had to be aged 75 years or older to be defined as an “older driver”. This age was chosen on the basis of a parallel study (Thompson, et al., 2010), which found that drivers of this age were significantly more likely to be seriously or fatally injured when involved in a crash than drivers below this age. They were also required to hold a driver’s

licence for a car (class C licence, entitling a person to drive non-commercial motor vehicles not exceeding 4,500kg), have driven at least once in the previous month, and speak fluent English.

The samples consisted of 28 participants from rural (10 females, 18 males) and 28 participants from urban (14 females, 14 males) areas of South Australia. Rural and urban participants were differentiated by their residential postcode. This was based on a classification of South Australia postcodes, used by Kloeden (2008), whereby urban areas (postcode between 5000 and 5199) were defined as the capital city, Adelaide, and regions within a 5 to 20 kilometre radius of the central business district. Rural areas (postcode between 5200 and 5999) were defined as those regions outside of the urban area. However, a distance limit of within a two-hour drive from the centre of the city (a radius of approximately 100 km) was necessary for practical reasons, as the researcher was unable to routinely travel larger distances to recruit participants and collect data. Participants ranged in age from 75 to 90. Rural participants had a mean age of 79.9 years ($SD = 3.8$) and urban participants 80.6 ($SD = 3.6$).

The current sample was compared to the population of licensed drivers aged 75 and over in South Australia for the year 2009 to determine whether it was representative. The licensing data were obtained from the South Australian Department of Planning, Transport and Infrastructure for individuals with a class C driver's licence. There were 60,602 licensed drivers aged 75 and over in 2009. Eighty-three per cent were in the 75-84 age group and 17% in the 85 and over group, compared to 84% and 16% for the sample. Therefore, the age composition of the sample closely approximated that of the broader population.

Materials

On-road driving was recorded using the 747ProS GPS Trip Recorder (hereafter referred to as Trip Recorder), which is a small device that is manufactured by TranSystem

Inc. (Hsinchu, Taiwan) and can be mounted onto the vehicle's dashboard (width = 47mm, length = 72mm, height = 20mm, weight = 65gm). It has 64MB of internal memory and, for this study, it was set to record location and time data every second. Depending on the strength of the satellite reception (which can be affected by tall buildings, inclement weather, tunnels, etc.), the accuracy of the information that the Trip Recorder provides is within three metres for location and to the nearest second for time. This level of accuracy is consistent with other GPS data loggers (Stopher, FitzGerald, & Zhang, 2008). It has a rechargeable battery (30 hours operation time, 300 hours standby time), but can be attached to the vehicle's AC power and synchronised to operate with the vehicle's ignition. Thus, it only records data when the ignition is on and the device is receiving power. This reduces use of the internal battery, as well as continually recharging it. It also groups the data into separate 'trips' (i.e., a section of driving in which the vehicle was started, driven and then stopped at a destination) because it starts recording when the vehicle is started and driven, and stops when the vehicle is turned off.

A computer program was developed by the researchers to analyse the data from the Trip Recorder, which provided information on each separate trip: date and time; distance (kilometres) and duration (minutes); the average, minimum and maximum speeds (km/hour); and total kilometres, minutes and average speed over the combined trips. Each trip could also be viewed as a line on a map, and a program was developed to colour-code the trip segments according to whether the vehicle was travelling at a speed of less than 100 km/h or 100 km/h and over. The program also allowed the user to select a segment of a trip by clicking on any two points on a line, which then displayed the distance (metres) between the two points and the time (seconds) that the vehicle took to travel between them.

As the GPS could not record trip purpose or identify the driver, additional information was obtained through a telephone-based 'Travel Diary'. This involved the researcher telephoning the participant on a daily basis during the one-week data collection period to

record the details of all of the driving that occurred in the vehicle(s) in which a Trip Recorder had been installed. Information was collected for each separate trip, including the date, the driver (for vehicles driven by more than one person, so that only data for the participating driver was analysed), start location, destination (where the trip ended), purpose (e.g., shopping), and the approximate start and end times.

Procedure

Data collection.

Attendees of the “Years Ahead” presentations who agreed and were eligible to participate in the study were visited at their residence by the researcher. Participants were provided with information relating to the nature and purpose of the research, and written consent was obtained. Next, a Trip Recorder was installed in the participant’s vehicle. If they drove multiple vehicles, a Trip Recorder was placed in each. The researcher (JPT) telephoned participants daily to record the Travel Diary data, and returned at the completion of the seven day period to remove the Trip Recorder and record the final Travel Diary information. All data were collected between June 2011 and June 2012.

In preparation for this study, the data collection procedures (Trip Recorder and Travel Diary) were evaluated using the current sample of participants (Thompson, Baldock, Mathias, & Wundersitz, 2013a). These analyses revealed that the distance that the participants travelled over a week, as measured by the Trip Recorder, closely corresponded to that measured by the odometers in their vehicles, thereby demonstrating the accuracy of the Trip Recorder. Furthermore, the majority of the individual trips that were recorded by the Trip Recorder were also reported in the Travel Diary, which demonstrated that the participants were reliable informants. Additionally, feedback from the participants regarding the study procedures was favourable in terms of ease and convenience.

Data preparation.

The GPS data for each participant were linked to the information from the Travel Diary in order to determine the driver and purpose of each trip. All trips made by non-participating drivers were excluded. Once a trip was linked to a specific purpose, it was classified as one of ten categories of activity in order to undertake a comparison between the rural and urban participants in terms of their access to specific categories of activities (an index of driver mobility). The ten categories were: ‘leisure activities’ (e.g., having a meal out), ‘social activities’ (e.g., visiting family/friends), ‘community activities’ (e.g., church), ‘shopping’, ‘medical/health care activities’ (e.g., doctor appointment or shopping at chemist, if the trip was for the driver and not for family or friends), ‘other errands’ (e.g., getting petrol), ‘errands for other people’ (e.g., transporting family/friends, including visits to the doctor), ‘return home’, ‘move car’ (i.e., a short distance), and ‘unknown’ (i.e., activity not identified). In addition, trips were grouped according to whether they were ‘discretionary’ (leisure, social and community activities) or ‘non-discretionary’ (shopping, medical/health care activities, other errands, errands for other people). Trips categorised as ‘return home’, ‘move car’ and ‘unknown’ were excluded from this latter classification because they were neither discretionary nor non-discretionary.

Where two purposes were given for a trip (e.g., travel to a shopping centre for both shopping and lunch with friends), both were counted equally and treated as separate activities. Thus, the total number of activities over the week could be greater than the number of trips. In addition, where participants stopped at a destination for an activity, but did not turn their car off before proceeding to another destination, this would result in two activities for one trip.

Each trip that a participant made was viewed on the map program in order to count the number of intersections that they drove through. These intersections were those where the driver had to actively respond or attend to the driving environment. These included:

signalised intersections, roundabouts, intersections where they turned from one road into another, intersections where they were required to give-way or stop, and railway crossings. Instances where they turned into a car park or driveway were not included. Information about an intersection (e.g. traffic lights, roundabouts) was provided on the map program, but some information (e.g. give-way/stop signs) could only be identified using ‘Street View’ in the Google Maps internet site (<http://maps.google.com/>), which provides a 360-degree street-level view of most roads. The total number of intersections for each participant was divided by both the total distance and total time that they drove over the week in order to calculate the number of intersections that they drove through per kilometre and minute driven.

Street View was used also to identify the sections of a participant’s trips that were on roads with a speed limit of 100 km/h or higher. The researcher would identify the driving route in the map display and examine the street-level images of the road in Street View to determine where speed limits started and ended, as indicated by street signage.

Data analysis.

The rural and urban groups were compared to determine whether they were demographically comparable (age, years of education, gender), after which they were compared in terms of their GPS and Travel Diary data. The first aim was to determine whether the rural participants drove longer distances than the urban participants, but were more restricted in their everyday driving mobility (i.e., fewer trips and discretionary activities), by comparing the amount (distance, time, and trips) that they drove over the week, as well as the number of activities that they undertook through their driving (for 10 categories of activity and discretionary/non-discretionary activities). The second aim was to determine whether the rural participants had a lower level of exposure to intersections in their driving than the urban participants, but a higher level of exposure to high-speed driving environments, by comparing the number of intersections that they drove through (total, per

kilometre, and per minute), the amount (distance and time) that they drove on sections of road with a speed limit of 100 km/h or higher, and the amount (distance and time) that they drove at speeds of 100 km/h or faster. Also in terms of risk-exposure, the age, and therefore safety, of their vehicles was compared.

Independent samples t , Mann-Whitney U and chi-square tests were used for the comparisons between the rural and urban participants in terms of demographics, mobility and exposure variables. Two-tailed tests were conducted, using an alpha of .05. In addition, Cohen's d effect sizes were calculated to evaluate the magnitude of the group differences, with $d = .2, .5$ and $.8$ equating to small, medium and large effect sizes, respectively (Cohen, 1992).

Results

Demographic comparison of rural and urban drivers

The rural and urban samples were firstly compared in order to determine whether they were demographically comparable. No significant differences were found between the groups in terms of their age, $t(54) = .73, p = .470$, years of schooling, $t(54) = 1.39, p = .170$, or gender composition, $\chi^2(1, N = 56) = 1.17, p = .280$, indicating that they were well-matched.

Driving mobility

The rural and urban participants were compared in terms of the distances driven, time spent driving and number of trips that they made over the one-week period. In Table 1, it can be seen that the mean distance (kilometres) driven by rural participants was significantly higher than the mean for urban participants and that the difference between these means was medium-to-large in size. However, there were no significant differences between them in terms of the mean time (minutes) that they spent driving or the mean number of trips that they

made. Thus, older rural drivers drove further over the one-week period than older urban drivers, but spent a similar amount of time driving and made a similar number of trips.

Table 1
Comparisons of Distance Driven, Time Spent Driving and Number of Trips over One Week of Driving between Rural and Urban Participants

	Rural Mean (SD)	Urban Mean (SD)	t	p	Cohen's <i>d</i> ^a
Distance driven (km)	165.6 (123.8)	94.8 (76.9)	2.57	.014*	.71
Time spent driving (mins)	233.7 (149.9)	209.0 (135.7)	.65	.521	
Number of trips	23.7 (11.9)	20.8 (10.9)	.98	.334	

^aCohen's *d* effect sizes were only calculated for statistically significant differences.

* *p* < .05.

The total activities of the rural and urban participants over the week, as well as the proportions that were grouped into each of the 10 categories of activity, are displayed in Table 2. A chi-square test revealed that there was a significant association between rural/urban residence and activity-type, $\chi^2(9) = 34.41$, *p* < .001. However, the small Cramer's V statistic of .16 indicates that only 3% of the variation in activity-type was explained by whether the driver lived in a rural or urban area. Both groups undertook a similar number of activities in the categories of: community, shopping, errands for other people, return home, move car and unknown activities (see Table 2). Small differences were notable in leisure activities and other errands, with rural participants undertaking more activities of this type. There were also small differences in social and medical/health care activities, with rural participants undertaking fewer activities of this type.

Table 2
Activities of Rural and Urban Participants by Activity Type, as well as Discretionary/Non-Discretionary Classification

	Rural % (n = 706)	Urban % (n = 632)
Leisure activities	6.9	4.4
Social activities	6.7	11.7
Community activities	9.5	8.9
Shopping	16.9	16.1
Medical/health care activities	3.5	5.9
Other errands	12.3	6.5
Errands for other people	5.0	6.0
Return home	30.5	32.0
Move car	2.1	3.6
Unknown	6.7	4.9
Total	100.0	100.0
<hr/>		
	Rural % (n = 429)	Urban % (n = 376)
Discretionary	38.0	42.0
Non-discretionary	62.0	58.0
Total	100.0	100.0

The total number of activities (excluding returning home, moving car and unknown activities), as well as the proportions that were discretionary and non-discretionary, for rural and urban participants are also displayed in Table 2. The association between rural/urban residence and discretionary/non-discretionary activities was not significant, $\chi^2(1) = 1.36, p = .244$. Thus, the groups undertook a similar amount of discretionary and non-discretionary activities.

Exposure to risk

The groups were then compared in terms of the number of intersections that they drove through. As seen in Table 3, the mean total number of intersections was lower for rural than urban participants, but this difference was not statistically significant. However, the means for rural participants in terms of intersections per kilometre and per minute driven were both significantly lower than those for urban participants and the differences between both sets of means were large in size. Thus, older rural drivers had a lower level of exposure to intersections (i.e. potential conflict points) on a per distance and time driven basis.

Table 3

Comparisons between Rural and Urban Participants in their Exposure to Intersections through One Week of Driving

	Rural Mean (SD)	Urban Mean (SD)	t	p	Cohen's <i>d</i> ^a
Total intersections	128.7 (83.8)	166.0 (113.3)	1.40	.168	
Intersections per km driven	1.1 (0.8)	1.9 (0.5)	4.43	< .001*	1.21
Intersections per min driven	0.6 (0.2)	0.8 (0.2)	4.73	< .001*	1.27

^aCohen's *d* effect sizes were only calculated for statistically significant differences.

* *p* < .05.

Next, the groups were compared in terms of the amount of driving done on roads with a speed limit of 100 km/h or higher. Table 4 shows that the mean distance travelled on such sections of road was higher for rural than urban participants. A non-parametric Mann-Whitney *U* test was used to test the significance of this difference because the data were non-normally distributed and included numerous zero values (e.g., 82% of urban participants did not travel on roads with these speed limits during the study period). This test indicated that the median distance driven on these sections of road by rural participants was significantly higher than that of the urban participants (see Table 4). In terms of time spent driving on such sections of road, the mean for rural participants was higher than that of the urban participants. Again, a Mann-Whitney *U* test revealed that rural participants had a significantly higher median time than urban participants.

Table 4
Comparisons between Rural and Urban Participants in their Exposure to High-Speed Driving Environments through One Week of Driving

	Rural	Urban	<i>U</i>	<i>p</i>	<i>z</i>
Distance (km) driven on roads with a speed limit of 100 km/h or higher					
Mean (<i>SD</i>)	79.8 (89.0)	3.5 (12.6)			
Median	64.9	0.0	614.00	< .001*	4.08
Time (mins) spent driving on roads with a speed limit of 100 km/h or higher					
Mean (<i>SD</i>)	54.7 (61.2)	2.4 (8.4)			
Median	43.9	0.0	614.00	< .001*	4.08
Distance (km) driven at speeds of 100 km/h or faster					
Mean (<i>SD</i>)	21.0 (40.3)	1.0 (5.2)			
Median	1.6	0.0	614.00	< .001*	4.18
Time (mins) spent driving at speeds of 100 km/h or faster					
Mean (<i>SD</i>)	11.9 (22.6)	0.6 (3.0)			
Median	0.9	0.0	614.00	< .001*	4.18

* *p* < .05.

The rural and urban drivers were then compared in terms of the distance and time that they drove at speeds of 100 km/h or faster. Table 4 shows that the mean and median distance for rural participants was higher than for the urban participants, which was supported by a significant Mann-Whitney *U* test. The mean and median time that rural participants drove at speeds of 100 km/h or faster was also statistically significantly higher than for the urban participants.

Finally, the two groups were compared in terms of the age of their vehicles. The mean of 9.0 (*SD* = 7.0) years for rural participants was lower than 11.4 (*SD* = 7.1) years for urban participants, but this difference was not significant, $t(54) = 1.26$, *p* = .214. Consequently, the age, and therefore the safety, of their vehicles was similar.

Discussion

This study was designed to determine whether older rural drivers are more restricted in their everyday driving mobility, and whether they have a higher level of exposure to risk while driving, than older urban drivers. To this end, the driving exposure and travel patterns of older drivers (aged ≥ 75) from rural and urban areas of South Australia were monitored for one week using GPS data loggers and telephone-based Travel Diaries. Consistent with our predictions, older rural drivers drove further than their urban counterparts in terms of the total distance travelled per week. It was also expected that, as a result of the distances that they have to travel, older rural drivers would make fewer trips than older urban drivers. However, the number of trips did not differ, suggesting that older rural drivers are not restricted in their driving mobility.

It was also thought that older rural drivers might prioritise their driving and neglect certain discretionary activities (e.g., social activities). While they did differ from older urban drivers in the extent to which they undertook certain types of activities, these differences were small. Furthermore, they did not differ in the number of activities that were deemed to be discretionary or non-discretionary, further suggesting that older rural drivers are not restricted in their driving mobility. This is a positive finding, given the abundance of research that highlights how important driving mobility is to the health and well-being of older adults (Adler, et al., 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Edwards, et al., 2009; Marottoli, et al., 2000; Marottoli, et al., 1997; Mezuk & Rebok, 2008).

Interestingly, despite travelling greater distances than their urban counterparts, rural drivers did not differ in the amount of time that they spent driving. This may be explained by the finding that they undertook a larger amount of driving at high speeds than urban drivers and so covered greater distances in the same amount of time. It may also be explained by there being fewer intersections on rural roads and less traffic congestion, which would reduce

their travel times. Additionally, it may be the case that older rural drivers are not dissuaded from undertaking trips and discretionary activities by the longer distances that they have to travel because they spend the same amount of time driving as older urban drivers. It could be that older drivers conceptualise the length of trips in terms of time rather than distance. Further research on perceptions of the importance of time- versus distance-driven would be needed in order to examine this hypothesis.

While it was predicted that the exposure of older rural drivers to intersections would be lower than that of older urban drivers, the two groups drove through a similar total number of intersections. However, this was likely to be due to the greater distances that the rural participants drove over the week. Indeed, they were exposed to fewer intersections on a per kilometre driven basis. Older rural drivers were also found to travel through fewer intersections per minute driven. Overall, the findings support Janke's (1991) suggestion that higher mileage drivers who travel on high-speed freeways encounter fewer intersections. Older rural drivers are exposed to less risk in terms of potential conflict points per distance and time driven than older urban drivers because of the roads that they travel on. It would be expected, therefore, that this would reduce their per distance driven crash rate. However, Hanson and Hildebrand (2011) found that rural drivers aged 81 and over had a higher crash rate per kilometre driven than their urban counterparts. While it may be the case that older rural drivers, despite their lower exposure to intersections per distance and time driven, are involved in more crashes than older urban drivers, other research by Thompson et al. (2010) has shown that they are involved in fewer total crashes, as well as crashes per head of population and per licensed driver. The findings of these studies may have differed due to differences in the samples, data and methods. Consequently, further research in this area may be required.

The exposure of older rural drivers to high-speed driving environments was clearly greater than that for older urban drivers. Older rural drivers travelled for longer distances and

for longer time periods than older urban drivers on roads with a speed limit of 100 km/h or higher and at GPS-measured speeds of 100 km/h or faster. Previous research has suggested that high-speed roads (Thompson, et al., 2013c) and high-speed travel (Archer, Fotheringham, Symmons, & Corben, 2008; Elvik, Christensen, & Amundsen, 2004; Kloeden, Ponte, & McLean, 2001; Richards, 2010) increase the likelihood of serious and fatal injury in a crash situation and this is likely to be exacerbated for older persons, given their susceptibility to increased injury severity (Li, et al., 2003; Viano, et al., 1990).

Consequently, future research should attempt to identify ways to reduce this exposure for older rural drivers, possibly through drivers avoiding areas with speed limits of 100 km/h or higher as much as possible. A second option would be to reduce the speed limit in these areas, in particular from 110 to 100 km/h. Long, Kloeden, Hutchinson, and McLean (2006) have previously shown that a reduction in the 110 km/h speed limit to 100 km/h on specific rural roads in South Australia reduced both the average travelling speed and the number of crashes in which there were casualties at these sites. Rural road users of all ages may be concerned about an increase in their travel times resulting from speed limit reductions, but Dutschke and Woolley (2010) have used data from Long et al. (2006) to demonstrate that there would only be small increases to travel times on rural roads in South Australia when speed limits are reduced from 110 to 100 km/h. An increase of between 4 and 10% was estimated, which only equates to between 2.2 and 5.5 minutes over a 100 km journey. Moreover, reductions in speed limits are likely to benefit the safety of drivers of all ages. A third option would be to encourage older rural drivers to purchase the newest vehicles that they can afford when they are in the market, as newer vehicles provide superior protection from serious or fatal injury in the event of a crash (Anderson & Doecke, 2010; Anderson & Hutchinson, 2010; Newstead, et al., 2008; Ryb, et al., 2009). The age of the rural and urban participants' vehicles was compared in this study and was found to be similar. However, given the increased injury-risk that older rural drivers face, and the fact that the average age

of their vehicles was found to be around nine years, there could be considerable gains in safety if older rural drivers chose newer vehicles.

Study limitations and future directions

There are a number of limitations that should be acknowledged. Firstly, the sample was small. However, there were statistically significant results and those relating to exposure to risk had low *p*-values of < .001. Therefore, the sample was large enough for these comparisons. Also, the non-significant results were far from significant at the *p* < .05 level, suggesting that additional participants would not have changed these results. Secondly, although there was no significant difference between the rural and urban groups in terms of gender composition, there were more males in the rural group than females. With small samples, this could have affected the rural/urban comparisons because the driving of older rural males may be overrepresented. Thirdly, the rural participants were recruited from areas that were relatively close to the capital city (i.e., within approximately two hours driving distance), which meant that older drivers from remote rural locations were not included. The proximity of the rural participants to the capital city, as well as the fact that many lived in retirement villages, large towns and regional centres, may mean that they had access to necessary services and encountered traffic conditions that were not too dissimilar to the fringe areas of Adelaide. Thus, it is likely that they had better access to services and more opportunities to socialise than individuals from remote locations. People residing in remote areas are likely to drive further to reach their destinations and, consequently, may have an even higher level of exposure to high-speed roads. It is also likely that their mobility may be more restricted if they have to drive further distances. Therefore, the differences between the rural and urban participants (number of trips and activities) may have been larger if remote drivers were included. Older drivers from remote areas should be recruited, if possible, in any future research on this topic.

Another limitation was that participants were recruited from senior citizens clubs and churches. These attendees, particularly those willing to volunteer for the study, may be healthier and more active than other adults of the same age. Indeed, that they were able to travel from their homes to these organisations suggests that they are mobile. Consequently, these rural participants may not have been deterred by driving longer distances, which may explain why they were not restricted in their number of trips or activities. Future research should therefore assess the health of the sample, and endeavour to include participants who vary in their health and mobility. The self-selected sample, and any consequent volunteer bias, is difficult to control. Indeed, it has been suggested that volunteer bias in driving studies is unavoidable because a truly random and representative sample would require mandatory participation, which is neither possible nor desirable (Lee, Cameron, & Lee, 2003; Molnar et al., 2013).

There may also have been a degree of bias in the sample because the participants were recruited from a driving safety presentation for older adults. People who are concerned enough about their driving, and road safety in general, to attend such a presentation may not be representative of all older drivers. In addition, they may have been more attuned to the issue of road safety when they participated in the study because they had recently attended the ‘Years Ahead’ presentation. As a result, it might have been anticipated that they would attempt to reduce their travelling speed while they were being monitored by the GPS logger. However, any such adjustments would have been equivalent across the rural and urban groups and the difference between them in terms of the amount that they drove at GPS-measured speeds of 100 km/h or faster was large. Therefore, it is unlikely that this sample bias had any considerable effects on the overall outcomes of the study.

Furthermore, it is possible that the participants altered the amount that they drove, their speed and/or their activities because their driving was being monitored. In particular, the placement of the Trip Recorder on the dashboards of their vehicles may have acted as a

visible reminder of the study. However, the participants who provided feedback regarding the data collection methods (Thompson, et al., 2013a) reported that they were not bothered by having the GPS device in their cars, that it did not affect their driving, that they did not change their normal driving routines because of the device, and that they tended to forget that it was present. Similarly, Blanchard, Myers, and Porter (2010) who used GPS devices to monitor the driving of older adults, also reported that the devices were barely noticeable and did not affect driving behaviour.

In addition, it was only possible to monitor one week of driving for each participant. Although data based on uncharacteristic weeks (e.g., where they went on a driving holiday or became unwell) were excluded, it is still possible that the week may have been atypical. Future research could monitor driving for a longer period to address this issue. This would, however, increase the already large amount of data provided by the GPS loggers, as well as the time required to analyse it. For present purposes, it was thought that an atypical week was equally likely to occur in either group, in which case any effects on the measurements of routine driving exposure and travel patterns are likely to be evenly distributed across groups.

It should also be noted that the data were collected over a 12-month period and so there may have been seasonal effects on travel behaviour. However, the rural and urban data were collected concurrently and, therefore, any such seasonal effects are also likely to be equal across groups.

Although this study investigated driving-based trips and activities, future research could examine rural/urban differences in trips by other means (e.g., walking, public transport), as these also play a large role in individual mobility. Given the distances that older rural persons have to travel and that alternative transportation is less available to them (Corcoran, James, & Ellis, 2005; Johnson, 1995; Thompson, Baldock, Mathias, & Wundersitz, 2013b), it would be expected that they would be less able to make such trips. Also, exposure to other hazardous aspects of the rural driving environment could be

examined. For example, as well as roads with a speed limit of 100 km/h or higher, Thompson et al. (2013c) found that undivided, unsealed, curved and inclined roads were more likely to be present in the crashes of older rural drivers and increased the likelihood of serious or fatal injury.

Conclusion

Recent research by Marottoli and Coughlin (2011) highlighted the importance of balancing the safety of older drivers while they are on the road with the competing need to maintain their mobility for as long as possible in order to optimise their quality of life. The present research indicates that this balance is particularly important for older drivers who live in rural areas. A greater proportion of their travel is undertaken on high-speed roads than is the case for older urban drivers, which increases their risk of serious or fatal injury in the event of a crash. One way of dealing with this increased risk would be to discourage them from using high-speed roads wherever possible. However, for many, this may not be possible, as it may be the only way that they can reach their destinations. Furthermore, their access to other transportation options, such as public transport and friends and family, is frequently limited in rural areas (Corcoran, et al., 2005; Johnson, 1995; Thompson, et al., 2013b). Other options include reducing speed limits in rural areas (e.g., 110 to 100 km/h) and encouraging older rural drivers to drive newer and safer vehicles, which should lower the risk of injury without affecting mobility.

References

- Adler, G., Rottunda, S., & Kuskowski, M. (1999). Dementia and driving: Perceptions and changing habits. *Clinical Gerontologist*, 20(2), 23-35. doi: 10.1300/J018v20n02_03
- Anderson, R. W. G., & Doecke, S. (2010). The relative age related crashworthiness of the registered South Australian passenger vehicle fleet. *Journal of the Australasian College of Road Safety*, 21(1), 36-46. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-21-1-Web1.pdf>
- Anderson, R. W. G., & Hutchinson, T. P. (2010). *In Australia, is injury less in recent cars than in earlier cars? Evidence from comparing the injury severities of two drivers in the same collision.* Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010706.pdf>
- Archer, J., Fotheringham, N., Symmons, M., & Corben, B. (2008). *The impact of lowered speed limits in urban and metropolitan areas* (Report No. 276). Clayton: Monash University Accident Research Centre. Retrieved from <http://www.monash.edu.au/miri/research/reports/muarc276.pdf>
- Baldock, M. R. J., Mathias, J. L., McLean, A. J., & Berndt, A. (2006). Self-regulation of driving and its relationship to driving ability among older adults. *Accident Analysis and Prevention*, 38, 1038-1045. doi: 10.1016/j.aap.2006.04.016
- Baldock, M. R. J., & McLean, A. J. (2005). *Older drivers: Crash involvement rates and causes* (Report No. CASR015). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://digital.library.adelaide.edu.au/dspace/bitstream/2440/36418/1/CASR015.pdf>
- Berry, C. (2011). *Can older drivers be nudged? How the public and private sectors can influence older drivers' self-regulation*. London: RAC Foundation. Retrieved from

http://www.racfoundation.org/assets/rac_foundation/content/downloadables/older_drivers_nudge-main_report-berry.pdf

Blanchard, R. A., Myers, A. M., & Porter, M. M. (2010). Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. *Accident Analysis and Prevention*, 42(2), 523-529. doi: 10.1016/j.aap.2009.09.018

Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155-159. doi: 10.1037/0033-295X.112.1.155

Corcoran, S., James, E. L., & Ellis, J. M. (2005). Do elderly Victorians in rural areas have access to public transport? *Road & Transport Research*, 14(1), 38-43. Retrieved from <http://www.arrb.com.au/Information-services/Publications/Issue.aspx?id=39>

De Raedt, R., & Ponjaert-Kristoffersen, I. (2000). The relationship between cognitive/neuropsychological factors and car driving performance in older adults. *Journal of the American Geriatrics Society*, 48(12), 1664-1668. Retrieved from <http://psycnet.apa.org/psycinfo/2000-12632-014>

Dutschke, J. K., & Woolley, J. E. (2010). Simulation of rural travel times to quantify the impact of lower speed limits. *Journal of the Australasian College of Road Safety*, 21(1), 46-56. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-21-1-Web1.pdf>

Edwards, J. D., Perkins, M., Ross, L. A., & Reynolds, S. L. (2009). Driving status and three-year mortality among community-dwelling older adults. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences*, 64A(2), 300-305. doi: 10.1093/gerona/gln019

Elvik, R., Christensen, P., & Amundsen, A. (2004). *Speed and road accidents: An evaluation of the Power Model* (Report No. 740/2004). Oslo: Institute of Transport Economics. Retrieved from

<https://www.toi.no/getfile.php/Publikasjoner/TØI%20rapporter/2004/740-2004/740-2004.pdf>

- Fonda, S. J., Wallace, R. B., & Herzog, A. R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *Journal of Gerontology: Social Sciences*, 56B(6), S343-S351. doi: 10.1093/geronb/56.6.S343
- Hakamies-Blomqvist, L., Raitanen, T., & O'Neill, D. (2002). Driver ageing does not cause higher accident rates per km. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(4), 271-274. doi: 10.1016/S1369-8478(03)00005-6
- Hanrahan, R. B., Layde, P. M., Zhu, S., Guse, C. E., & Hargarten, S. W. (2009). The association of driver age with traffic injury severity in Wisconsin. *Traffic Injury Prevention*, 10(4), 361-367. doi: 10.1080/15389580902973635
- Hanson, T. R., & Hildebrand, E. D. (2011). Are rural older drivers subject to low-mileage bias? *Accident Analysis and Prevention*, 43(5), 1872-1877. doi: 10.1016/j.aap.2011.04.028
- Hough, J. A., Cao, X., & Handy, S. L. (2008). Exploring travel behavior of elderly women in rural and small urban North Dakota. *Transportation Research Record: Journal of the Transportation Research Board*, 2082, 125-131. doi: 10.3141/2082-15
- Janke, M. K. (1991). Accidents, mileage, and the exaggeration of risk. *Accident Analysis and Prevention*, 23(2-3), 183-188. doi: 10.1016/0001-4575(91)90048-A
- Johnson, J. E. (1995). Rural elders and the decision to stop driving. *Journal of Community Health Nursing*, 12(3), 131-138. doi: 10.1207/s15327655jchn1203_1
- Kahane, C. J. (2013). *Injury vulnerability and effectiveness of occupant protection technologies for older occupants and women* (Report No. DOT HS 811 766). Washington DC: National Highway Traffic Safety Administration. Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811766.PDF>

- Kloeden, C. N. (2008). *The crash and offence experience of newly licensed young drivers* (Report No. AP-R331/08). Sydney: Austroads. Retrieved from <https://www.onlinepublications.austroads.com.au/items/AP-R331-08>
- Kloeden, C. N., Ponte, G., & McLean, A. J. (2001). *Travelling Speed and the risk of crash involvement on rural roads* (Report No. CR204). Canberra: Australian Transport Safety Bureau. Retrieved from http://www.infrastructure.gov.au/roads/safety/publications/2001/Rural_Speed_1.aspx
- Langford, J. (2009). Older driver crashes. In M. Odell (Ed.), *Older road users* (pp. 1-23). Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.
- Langford, J., Methorst, R., & Hakamies-Blomqvist, L. (2006). Older drivers do not have a high crash risk - A replication of low mileage bias. *Accident Analysis and Prevention*, 38(3), 574-578. doi: 10.1016/j.aap.2005.12.002
- Lee, H. C., Cameron, D., & Lee, A. H. (2003). Assessing the driving performance of older adult drivers: On-road versus simulated driving. *Accident Analysis and Prevention*, 35(5), 797-803. doi: 10.1016/S0001-4575(02)00083-0
- Li, G., Braver, E. R., & Chen, L. H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis and Prevention*, 35(2), 227-235. doi: 10.1016/S0001-4575(01)00107-5
- Long, A. D., Kloeden, C. N., Hutchinson, T. P., & McLean, A. J. (2006). *Reduction of speed limit from 110km/h to 100km/h on certain roads in South Australia: a preliminary evaluation* (Report No. CASR024). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://casr.adelaide.edu.au/casrpublish/show.php?id=566>
- Marottoli, R. A., & Coughlin, J. F. (2011). Walking the tightrope: Developing a systems approach to balance safety and mobility for an aging society. *Journal of Aging and Social Policy*, 23(4), 372-383. doi: 10.1080/08959420.2011.605655

- Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., & Berkman, L. F. (2000). Consequences of driving cessation: Decreased out-of-home activity levels. *Journal of Gerontology: Social Sciences*, 55B(6), S334-S340. doi: 10.1093/geronb/55.6.S334
- Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive symptoms: Prospective evidence from the New Haven Established Populations for Epidemiological Studies of the Elderly. *Journal of the American Geriatrics Society*, 45(2), 202-206. Retrieved from <http://psycnet.apa.org/psycinfo/1997-07396-004>
- Meuleners, L. B., Harding, A., Lee, A. H., & Legge, M. (2006). Fragility and crash over-representation among older drivers in Western Australia. *Accident Analysis and Prevention*, 38(5), 1006-1010. doi: 10.1016/j.aap.2006.04.005
- Mezuk, B., & Rebok, G. W. (2008). Social integration and social support among older adults following driving cessation. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 63B(5), S298-S303. doi: 10.1093/geronb/63.5.S298
- Molnar, L. J., Charlton, J. L., Eby, D. W., Bogard, S. E., Langford, J., Koppel, S., . . . Manso-Hing, M. (2013). Self-regulation of driving by older adults: Comparison of self-report and objective driving data. *Transportation Research Part F: Traffic Psychology and Behaviour*, 20, 29-38. doi: 10.1016/j.trf.2013.05.001
- Newstead, S., Watson, L., & Cameron, M. (2008). *Vehicle safety ratings estimated from police reported crash data: 2008 update* (Report No. 280). Melbourne: Monash University Accident Research Centre. Retrieved from <http://www.monash.edu.au/miri/research/reports/muarc280.pdf>
- Nordbakke, S. (2013). Capabilities for mobility among urban older women: Barriers, strategies and options. *Journal of Transport Geography*, 26, 166-174. doi: 10.1016/j.jtrangeo.2012.10.003

- Oxley, J., & Whelan, M. (2008). It cannot be all about safety: The benefits of prolonged mobility. *Traffic Injury Prevention*, 9(4), 367-378. doi: 10.1080/15389580801895285
- Rakotonirainy, A., Steinhardt, D., Delhomme, P., Darvell, M., & Schramm, A. (2012). Older drivers' crashes in Queensland, Australia. *Accident Analysis and Prevention*, 48, 423-429. doi: 10.1016/j.aap.2012.02.016
- Richards, D. C. (2010). *Relationship between speed and risk of fatal injury. Pedestrians and car occupants* (Report No. RSWP 16). London: Department for Transport. Retrieved from <https://www.gov.uk/government/policies/making-roads-safer>
- Ryan, G. A., Legge, M., & Rosman, D. (1998). Age related changes in driver's crash risk and crash type. *Accident Analysis and Prevention*, 30(3), 379-387. doi: 10.1016/S0001-4575(97)00098-5
- Ryb, G. E., Dischinger, P. C., & Ho, S. (2009). Vehicle model year and crash outcomes: A CIREN study. *Traffic Injury Prevention*, 10(6), 560-566. doi: 10.1080/15389580903271401
- Stopher, P., FitzGerald, C., & Zhang, J. (2008). Search for a global positioning system device to measure person travel. *Transportation Research Part C*, 16(3), 350-369. doi: 10.1016/j.trc.2007.10.002
- Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2010). *Older drivers in rural and urban areas: Comparisons of crash, serious injury, and fatality rates*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010672.pdf>
- Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2013a). *The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Brisbane, Queensland. Retrieved from

<http://acrs.org.au/files/arsrpe/Paper%2025%20-%20Thompson%20-%20Research%20Methods.pdf>

Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2013b). Do older rural drivers self-regulate their driving? The effects of increased driving importance and limited alternative transportation. *Journal of the Australasian College of Road Safety*, 24(1), 30-42. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRSjournalVol24No1Feb13WEBv2.pdf#page=30>

Thompson, J. P., Baldock, M. R. J., Mathias, J. L., & Wundersitz, L. N. (2013c). An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers. *Accident Analysis and Prevention*, 50, 768-775. doi: 10.1016/j.aap.2012.06.028

Viano, D. C., Culver, C. C., Evans, L., & Frick, M. (1990). Involvement of older drivers in multivehicle side-impact crashes. *Accident Analysis and Prevention*, 22(2), 177-188. doi: 10.1016/0001-4575(90)90068-V

Whitehead, B. J., Howie, L., & Lovell, R. K. (2006). Older people's experience of driver licence cancellation: A phenomenological study. *Australian Occupational Therapy Journal*, 53(3), 173-180. doi: 10.1111/j.1440-1630.2006.00564.x

Chapter 8 : Summary and Conclusions

Overview

The overall aim of this thesis was to examine both the safety and mobility of older drivers who live in rural or remote areas of South Australia in comparison to their urban counterparts. A review of previous research relating to the safety and mobility of older drivers in general was undertaken in Chapter 1 in order to provide a background to the thesis. This review indicated that older drivers have an increased risk of being seriously or fatally injured in a crash compared to drivers in younger age groups. At the same time, however, the mobility that driving provides to them is important for their health and well-being. This was followed by a review in Chapter 2 of past research specifically relating to the safety and mobility of older drivers from rural areas. The review in Chapter 2 suggested that the circumstances of living in rural areas (e.g. longer distances to travel, increased driving importance, limited alternative transportation, roads with high speed limits) may both increase the risk of serious and fatal injury for older drivers and restrict their mobility.

As a result of the literature reviewed in Chapters 1 and 2, specific objectives were established for this research. The first was to determine whether older rural drivers have an increased likelihood of being seriously or fatally injured when involved in crashes compared to older urban drivers. The second objective was to determine whether certain environmental, driver and vehicle factors that are more common in the crashes of older rural drivers, compared to older urban drivers, contribute to an increased risk of serious or fatal injury. The third objective was to determine whether older rural drivers are less able to self-regulate their driving, compared to older urban drivers, due to the importance that they place on driving and the lower availability of alternative transportation. The final objective was to determine whether older rural drivers are more restricted in their day-to-day driving mobility than older

urban drivers and whether they differ in their exposure to risk (i.e. intersections and high-speed roads) when driving.

This final chapter begins with a summary of the methods, aims and key findings of the individual studies. Following this, the broader implications of this research are discussed and recommendations to improve both the safety and mobility of older rural drivers are made. Finally, the methodological strengths and limitations of this research, as well as possible directions for future research on rural and urban older drivers, are discussed.

Summary of Findings

Studies 1 and 2.

The first two studies (Chapters 3 and 4) involved analysis of five years of crash, serious injury, and fatality data for drivers of all age groups from both rural and urban areas of South Australia. The goal of Study 1 was to compare the crash, serious injury, and fatality rates of older drivers and drivers in younger age groups, and also compare the rates of older rural drivers and older urban drivers. It was found that older drivers (aged 65 years and over) had fewer crashes than all other age groups and that this was still the case when differences between the age groups, in terms of population numbers and amount of licensure, were taken into account. This trend in crash involvement was found for both rural and urban drivers. Drivers aged 75 years and older, however, had a greater likelihood than drivers in younger age groups of being involved in crashes that resulted in a serious or fatal injury to themselves or any other person who was involved. When the crash, serious injury, and fatality rates were compared between rural and urban drivers of all ages, it was found that rural drivers had fewer crashes, but were more likely to be involved in serious or fatal injury crashes. Moreover, it was found that rural drivers aged 75 years and older were more than twice as likely to be involved in crashes that resulted in a serious or fatal injury than urban drivers of the same age. Therefore, the overall conclusion was that drivers aged 75 and older who live

rurally have the highest risk of serious injury and fatality from the crashes in which they are involved, when compared to drivers of all other ages and residential locations.

Study 2 was designed to examine the environmental, driver and vehicle factors that are involved in the crashes of rural and urban older drivers, as well as the association between these factors and the risk of serious or fatal injury in drivers of all ages. It was found that certain environmental variables (i.e. undivided, unsealed, curved and inclined roads, and areas with a speed limit of 100km/h or greater), which were more likely to be present in the crashes of older rural drivers, increased the chances that crash-involved drivers would be seriously or fatally injured. In particular, crashing on a road with a speed limit of 100 km/h or greater produced the largest increase in the risk of serious or fatal injury to the driver.

Study 3.

For Study 3 (Chapter 5), a sample of 170 older drivers were recruited from rural and urban areas of South Australia. To be eligible, participants had to be aged 75 years or older. This age was chosen to define an “older driver”, instead of the conventional age of 65 years and older, on the basis of the finding in Study 1 that drivers aged 75 years or older were significantly more likely to be seriously or fatally injured when involved in a crash than drivers below this age. The participants completed a questionnaire on the importance that they attribute to their driving, their access to alternative transportation and the degree to which they self-regulate their driving. It was found that rural participants viewed their driving as more important than urban participants and believed that they had fewer alternative transportation options available to them. However, they did not differ on various indices of self-regulation, specifically: avoidance of difficult driving situations, reductions in amount of driving and willingness to stop driving. Thus, the self-regulatory practices of older rural drivers did not appear to be restricted by greater perceived driving importance or limited alternative transportation.

Studies 4 and 5.

In Study 4 (Chapter 6), the driving exposure and travel patterns of a sample of 56 drivers (aged ≥ 75) from rural and urban areas of South Australia (who were a sub-sample of the 170 drivers in Study 3) were monitored for a period of one week. This was undertaken using both objective (Global Positioning System data loggers, vehicle odometer readings) and subjective (self-report telephone-based travel diaries) methods. Subsequent interviews regarding the data collection process were also undertaken with a subset of 16 participants. The purpose of this study was to evaluate the viability and accuracy of using both objective GPS-based methods and subjective self-report methods for measuring driving exposure with older road users. It was found that these methods of data collection provided a broad range of accurate information relating to driving exposure and travel patterns for all participants. In addition, the participants who were interviewed provided favourable feedback regarding the data collection process. Therefore, both objective and subjective data collection methods were useful for obtaining important driving exposure information and these methods were acceptable to older adults.

Following on from the preliminary evaluation in Study 4, the associated driving exposure and travel pattern data were analysed in Study 5 (Chapter 7) in terms of the everyday driving mobility and exposure to risk of rural and urban older drivers. With respect to mobility, rural participants drove further over the week than urban participants, but did not differ in the number of trips that they made or the number of trips that were made for discretionary and non-discretionary activities. In terms of risk-exposure, rural participants were exposed to fewer intersections (potential conflict points) in their driving (per distance and time driven) than urban participants, but drove further and for longer periods on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster. The overall conclusion was that older rural drivers are not less mobile, but have a higher

exposure to high-speed road conditions that are more likely to lead to serious or fatal injuries in the event of a crash.

Implications of the Findings

The safety of older rural drivers.

In Study 1 it was shown that drivers aged 65 years and older have fewer crashes than younger drivers in terms of total crashes, crashes per head of population and crashes per licensed driver, which is consistent with previous research (Baldock & McLean, 2005; Fildes, et al., 1994; Lyman, et al., 2002; Ryan, et al., 1998). It was also found that, across all ages, rural drivers have fewer crashes than urban drivers. This is consistent with previous research by Zwerling et al. (2005), which demonstrated that rural drivers in the USA have a lower total number of crashes than urban drivers. Consequently, Study 1 highlighted the fact that older drivers from rural areas have the lowest rates of crash involvement when compared to all other driver groups, regardless of age or residential locality. Other research from the USA has similarly indicated that older rural drivers are involved in fewer crashes than older urban drivers (Finison & Dubrow, 2002; Foley, et al., 1995; Zwerling, et al., 2005).

Previous studies have also examined crash rates on a per distance driven basis for different age groups and have found that older drivers have elevated rates (Baldock & McLean, 2005; Li, et al., 2003; Lyman, et al., 2002; Ryan, et al., 1998). However, this may be due to the fact that older drivers travel shorter distances, on average, than younger drivers (Baldock & McLean, 2005; Ryan, et al., 1998) and may therefore undertake most of their driving on local roads that have more potential conflict points (Janke, 1991). In comparison, drivers who travel large distances may do much of their driving on high-speed freeways that have fewer potential conflict points. This may result in an over-estimation of the crash involvement of older drivers per distance driven and is referred to as the ‘low mileage bias’ (Janke, 1991; Langford, 2009).

Low mileage bias has implications for the findings of the present study because older rural drivers were found in Study 5 to travel further distances on high-speed roads than older urban drivers. Indeed, the low rates of crash involvement for older rural drivers in Study 1 could be due to their being exposed to relatively few potential conflict points (i.e. intersections) per distance and time driven, as was also found in Study 5. However, research from Canada by Hildebrand et al. (2000 as cited in (Hanson & Hildebrand, 2011b) compared the collision rates per million kilometres driven of rural and urban drivers from various age groups. This study by Hildebrand et al. found that rural drivers had lower collision rates in all of the age groups, except for rural drivers in the 81 years and older group who actually had higher crash rates than urban drivers. Crash rates on a per kilometre driven basis for rural and urban drivers were not examined in the present study as these data were not available. However, it has been suggested that total crash involvement and crash involvement per licensed driver are the most meaningful rates to consider (Baldock & McLean, 2005; Maycock, 1997). This is because total crash involvement indicates the extent to which a given group contributes to a jurisdiction's crash numbers and crash involvement per licensed driver indicates the risk related to granting a licence to a typical member of that group (Baldock & McLean, 2005). Consequently, using these rates alone, it seems that, overall, older rural drivers are involved in fewer crashes than their urban counterparts.

Older drivers, in general, have previously been shown to have a high risk of being seriously or fatally injured when they are involved in crashes compared to younger drivers (Baldock & McLean, 2005; Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meuleners, et al., 2006; Rakotonirainy, et al., 2012; Ryan, et al., 1998). This has been attributed to increased fragility, in that older people have a lower tolerance to physical trauma and sustain more severe injuries than younger persons in similar crashes (Evans, 1988; Li, et al., 2003; Viano, et al., 1990; Viano, et al., 1989). The increased risk of serious and fatal injury for older drivers was again shown to be the case in Study 1. Furthermore, previous research has shown

that drivers of all ages who live in rural areas are at a higher risk of serious or fatal injuries following a crash than drivers who reside in urban areas (Borgialli, et al., 2000; Brown, et al., 2000; Donaldson, et al., 2006; Du, et al., 2007; Maio, et al., 1992; Mitchell & Chong, 2010; Muelleman, et al., 2007). Again, this finding was replicated in Study 1. However, one of the most important findings in the current research was that rural drivers aged 75 and over were shown in Study 1 to be more than twice as likely to be seriously or fatally injured when involved in a crash than urban drivers of the same age. This suggests that there are factors, other than fragility, that increase the risk of serious and fatal injury specifically for older drivers who live in rural areas.

Indeed, it was shown in Study 2 that the higher risk for older rural drivers was due, at least in part, to certain environmental factors that were more common in their crashes. Of particular concern are roads with a speed limit of 100 km/h or higher. Research by Gonzalez et al. (2007) from Alabama, USA, has also suggested that the higher speed limits in rural areas increase mortality rates for drivers of all ages. In Study 2 it was shown that, if an older driver crashes on a road with this speed limit, they are four and a half times more likely to be seriously or fatally injured than if they crash on a road with a speed limit of 90 km/h or lower. Furthermore, Study 5 revealed that older rural drivers had a higher level of exposure to these high-speed driving conditions than older urban drivers. These findings not only highlight the importance of research that focuses specifically on the safety of older rural drivers, but also identify one of the main characteristics of rural road environments that increase their risk. Possible ways to reduce this risk for older rural drivers are discussed in the Recommendations section below.

The findings of this research also have implications for the definition of “older drivers”. Previously, the age range that has most commonly been used to define older drivers has been 65 years and older (Kostyniuk & Shope, 2003). However, in Study 1 of the present research, drivers aged 75 years and older (both rural and urban) were significantly more likely

to be seriously or fatally injured when involved in a crash than drivers below this age. For this reason, the age range of 75 or older was used to define older drivers in all subsequent studies. This re-classification reflects the age at which the likelihood of serious or fatal injury from crashes increases; which is consistently reported to be an issue for older drivers (Baldock & McLean, 2005; Hanrahan, et al., 2009; Langford & Koppel, 2006a; Meuleners, et al., 2006; Rakotonirainy, et al., 2012; Ryan, et al., 1998) and is the foundation of much of the research into their road safety. This older age range is also consistent with notions that people are living longer and healthier lives, and that their health, abilities and tolerance to injuries may not decline until later in life compared with previous cohorts. Furthermore, recent research by Classen, Wang, Crizzle, Winter, and Lanford (2013) found that male and female drivers aged over 75 were 3.2 and 3.5 times more likely to fail an on-road driving evaluation than male and female drivers aged between 63 and 75, respectively. Indeed, they found no evidence that younger older adults (aged 65 to 75) were at a high risk of failing an on-road evaluation. Consequently, it was suggested that more emphasis should be placed on the over 75 age group in terms of future investigations of the driving performance of older adults. The findings of Classen et al. and the present research also suggest that, if mandatory age-based testing of fitness-to-drive is to be retained or implemented in various jurisdictions, the appropriate age should be no younger than 75.

Recommendations to improve safety.

The present research demonstrates that, in regard to the safety of older rural drivers, it is not the number of crashes that they are involved in that is of concern; rather the fact that when they crash, they have an increased likelihood of being seriously or fatally injured. Consequently, the goal should be to reduce their risk of serious or fatal injury. There are several ways to achieve this. Firstly, research by Boufous, Finch, Hayen and Williamson (2008) has suggested that environmental modifications may reduce the severity of injury in

older people who are involved in road crashes. Specific modifications could be made to the rural driving environment, based on the factors that were found in Study 2 to increase the chances that a driver would be seriously or fatally injured in a crash. These factors include undivided, unsealed, curved and inclined roads, and areas with a speed limit of 100km/h or greater. The potential changes, which were outlined previously (Study 2 Discussion), include:

- Using centre-of-the-road wire rope barriers to divide previously undivided rural roads,
- Maintaining or sealing the surface of unsealed rural roads to improve the traction on these surfaces,
- Sealing the shoulders of curved rural roads and providing superior delineation to reduce the number of instances in which drivers lose control of their vehicles,
- Ensuring sufficient sight distance around curves on rural roads, and
- Reducing the number of road junctions that are adjacent to curved roads and crests of hills on rural roads.

While it is acknowledged that not all undivided, unsealed and curved rural roads, or sections of rural roads located at the crest of a hill, can be improved in these ways, prioritised improvements to roads should produce long term benefits. These changes would be expected to improve safety for road users of all ages, particularly drivers aged 75 or over.

Crashing on a road with a speed limit of 100 km/h or greater was the environmental factor that was found in Study 2 to produce the largest increase in the risk of serious or fatal injury to the driver. High-speed travel is known to be associated with an increased likelihood of serious or fatal injury in a crash situation (Archer, Fotheringham, Symmons, & Corben, 2008; Elvik, Christensen, & Amundsen, 2004; Kloeden, Ponte, & McLean, 2001; Richards, 2010). Furthermore, it was found in Study 5 that older rural drivers have a higher exposure to roads with these speed limits than older urban drivers. One way of dealing with this increased risk would be to dissuade older drivers from using roads with these speed limits as much as possible. However, for many, this may not be possible, as it may be the only way that they

can reach their destination. Another option would be to reduce the speed limit on rural roads - from 110 to 100km/h - in order to decrease the likelihood and level of severity of rural crashes. Long et al. (2006) have previously demonstrated that a reduction in the 110 km/h speed limit to 100 km/h on particular rural roads in South Australia reduced both the average travelling speed and the number of crashes in which there were casualties at these locations. Such safety benefits of lower speed limits have also previously been demonstrated by research from many parts of the world, such as the Netherlands (Jaarsma, Louwerse, Dijkstra, de Vries, & Spaas, 2011), the USA (Baum, Wells, & Lund, 1990; Ossiander & Cummings, 2002) and Sweden (Johansson, 1996). One of the most common objections to such speed limit reductions is that there will be associated increases in travel times for rural road users. However, using data from Long et al. (2006), Dutschke and Woolley (2010) have indicated that there would only be small increases in travel times on rural roads in South Australia when speed limits are reduced from 110 to 100 km/h. An increase of between 4 and 10% was predicted, which only equates to between 2.2 and 5.5 minutes over a 100 km journey. Furthermore, such reductions in speed limits, in addition to having only a small effect on travel times, are likely to benefit the safety of drivers of all ages, not just older drivers.

Another way of dealing with the increased injury risk posed by the aforementioned environmental factors is to encourage older rural drivers to drive vehicles that are as new as possible. Newer cars provide superior protection from serious or fatal injury in the event of a crash (Anderson & Doecke, 2010; Anderson & Hutchinson, 2010; Newstead, Watson, & Cameron, 2008; NHTSA, 2013c; Ryb, Dischinger, & Ho, 2009). Thus, it would be beneficial if family, friends and professionals (e.g. general practitioners, social workers, occupational therapists, road safety advocates) could assist older rural drivers to choose the newest and safest vehicles that they can afford when they are in the market for a new vehicle. This is important because it has been shown by several studies that vehicle safety is not well understood by older adults and is not considered a high priority when they are in the process

of purchasing a vehicle, with price, vehicle handling and fuel economy considered to be most important (Charlton, Fildes, & Andrea, 2002; Eby & Molnar, 2012; Koppel, Clark, Hoareau, Charlton, & Newstead, 2013; Zhan & Vrkljan, 2011). For example, Koppel et al. (2013) surveyed older adults from the eastern Australian states of Victoria, New South Wales, and Queensland who had recently purchased a new or used vehicle. It was found that they were more likely to identify price, rather than design or Australasian New Car Assessment Program (ANCAP) rating, as their most important consideration in the process of purchasing a vehicle. However, safety-related features were viewed as being important features of a vehicle. It was concluded:

That, though older consumers highlight the importance of safety features (i.e. seat belts, air bags, braking), they often downplay the role of safety in their vehicle purchasing process and are more likely to equate vehicle safety with the presence of specific vehicle safety features or technologies rather than the vehicle's crash safety/test results or crashworthiness. (p. 592)

Thus, this study suggests that there are still considerable improvements to be made in terms of older drivers' knowledge of vehicle safety and the importance they attach to it when choosing a new vehicle to buy. It is important that the benefits of newer and safer vehicles are promoted to older drivers and particularly those who live in rural areas, given their greater risk of serious and fatal injuries. This could be achieved through more widespread advertising of ANCAP data relating to vehicle test results and crashworthiness ratings.

The potential benefits of getting older adults to drive newer and safer vehicles are likely to be substantial. Indeed, recent research by Budd, Scully, Newstead, and Watson (2012) has attempted to estimate the likely injury reduction benefits that could be obtained through safer vehicle choices by older drivers in both Australia and New Zealand. This research indicated that, if cost was not a factor and older drivers were successfully encouraged to choose vehicles with an optimal level of safety, serious injury and fatal crash

reductions of up to 90% might be obtained. They also showed that if safe vehicle choices were restricted to popular (affordable) models manufactured in the year 2000 or later, reductions of up to 37% could still be achieved. The potential reductions in serious and fatal crashes may be even larger for older rural drivers.

Furthermore, other research (Eby & Molnar, 2012; Herriots, 2005; Shaheen & Niemeier, 2001) has suggested that future vehicle designs and technology could be adapted to make driving both easier and safer specifically for older adults. Eby and Molnar (2012) proposed that:

The development of vehicle design features, new automotive technologies, and crashworthiness systems in the future should be guided by both knowledge of the effects of frailty/fragility of the elderly on crash outcomes, as well as knowledge of common driving-related declines in psychomotor, visual, and cognitive abilities. (p. i)

Thus, improvements in future vehicles may help older drivers to overcome common driving-related declines in functional abilities and, therefore, potentially reduce their risk of crash involvement. In so doing, this could also assist them to continue driving for longer. Furthermore, improvements to the crashworthiness of vehicles, which are designed and tested with the frailty/fragility of older adults in mind, may provide better protection from injury in a crash. In the context of the present research, such vehicle improvements would be particularly beneficial to older rural drivers, given their increased severity of injuries resulting from crashes.

Eby and Molnar (2012) identified some areas of vehicle design that could be improved in order to make driving easier and safer for people who are experiencing age-related functional declines. These areas included: the ease of getting in and out of the vehicle, the comfort of the seating, the visibility of the external driving environment, the ease of using the cargo areas, and the ease of using the dashboard controls. Next, they reviewed a range of new vehicle technologies that could be beneficial to older adults who are experiencing age-related

functional declines. These included: night vision enhancement systems, forward collision warning systems, adaptive cruise control systems, lane departure warning systems, navigation assistance systems, and automatic crash notification systems (ACN systems are discussed in detail in the following paragraph). Eby and Molnar acknowledge, however, that these new technologies would need to be affordable, easy, and safe for older drivers to use. Finally, they also identified the areas where recent advances in crashworthiness of vehicles had been made and opportunities for further improvements to provide better protection for older adults. These areas included: structural design, seat belts, and airbags. They also suggest that the design and testing of crashworthiness improvements need to be based on injury assessment reference values that are applicable to older adults and not a one-size-fits-all standard. Overall, Eby and Molnar suggest that there is an opportunity to improve the safety, mobility, and quality of life of older adults by designing vehicles and vehicle technologies that help overcome common age-related deficits. However, they acknowledge that the marketing of these vehicles to older consumers will be challenging, particularly if they are identified as being specifically for older adults or people with disabilities. Further market research will be needed to choose an effective set of messages to sell such vehicles.

Finally, previous research has suggested that rural drivers of all ages are more likely to be seriously or fatally injured from a crash than urban drivers as a result of delays in the delivery of medical care to rural crash sites (Bentham, 1986; Brodsky & Shalom Hakkert, 1983; Clark, 2003; Leicht, et al., 1986; Muelleman & Mueller, 1996). Therefore, another way to reduce the risk of serious or fatal injury for older rural drivers would be to reduce the average time taken to provide emergency medical care at crash sites. Although an argument could be made for the provision of more emergency medical services in rural areas, such a solution is likely to be cost-prohibitive. A better way of reducing delays in medical care could come from reducing delays in notification of emergency services that a crash has occurred. It is likely that delays in medical care result from the fact that some rural roads have little

traffic, meaning delays in witnesses arriving to detect the crash and to contact emergency services. The development of in-vehicle technology, commonly referred to as Automatic Crash Notification (ACN), may have the potential to address this issue (Champion et al., 2004; Clark & Cushing, 2002; Johnstone, 2004; Ponte, Anderson, & Ryan, 2013; Sihvola, Luoma, Schirokoff, Salo, & Karkola, 2009; White, Thompson, Turner, Dougherty, & Schmidt, 2011). When a vehicle with ACN technology is involved in a crash, it automatically detects the incident (e.g. through airbag deployment, rollover sensor, accelerometer). It also obtains information from the vehicle's on-board diagnostic module about the severity of the impact, as measured by in-vehicle sensors (e.g. change in velocity, whether a rollover was detected). It can then alert emergency medical services if necessary and send GPS-based coordinates of the location of the crash. This technology may therefore reduce the time-to-treatment for individuals involved in rural crashes and thereby decrease road fatalities and injury severity (Clark & Cushing, 2002; Ponte, et al., 2013; Sihvola, et al., 2009). While it may be beneficial for all older rural drivers to drive vehicles that include this technology, it is still being developed and has not yet been widely deployed in vehicles manufactured for the Australian market. The rate at which safety features permeate the vehicle fleet can also take more than a decade in Australia (Anderson, Hutchinson, Linke, & Ponte, 2011), although it may become possible to retro-fit ACN systems to older vehicles.

The mobility of older rural drivers.

Study 5 revealed that older rural drivers travelled further over a period of one week than older urban drivers. This is consistent with research from the USA (Mattson, 2013; Pucher & Renne, 2005) which has demonstrated that rural drivers of all ages travel, on average, a larger distance per individual driving trip, per day, and per year than urban drivers. However, despite the longer distances that need to be driven in rural and remote areas, the results of this research suggest that the mobility of older rural drivers is not restricted in

comparison to their urban counterparts. Indeed, older rural drivers made as many trips over the period of one week as older urban drivers. This contradicts research by Hough et al. (2008), which found that women aged 65 years and older in rural areas of North Dakota, USA, tended to make fewer trips than older women living in small urban areas. However, it is consistent with research from the USA by Mattson (2013), which indicated that rural drivers aged 75 and older make the same number of trips per day as urban drivers of the same age.

Study 5 also found that older rural drivers undertook as many discretionary and non-discretionary activities through their driving as older urban drivers. This again contradicts Hough et al. (2008), who found that rural older women travel less often than older women from small urban areas particularly for certain activities, such as going to a restaurant, a friend's house, a store, a hair salon, or an exercise place. However, it should be noted that, while Hough et al. focussed on the travel patterns of older women, the present study did not examine men and women separately (because the participant numbers for separate analyses would have been small), which may account for different results.

While older rural drivers did differ in Study 5 from older urban drivers in the extent to which they undertook certain types of activities, these differences were small. Specifically, they performed some activities less often (i.e. social and medical/health care activities) and others more often (i.e. leisure activities and other errands). Therefore, the present research suggests that older rural drivers do not have to prioritise their driving and neglect certain types of activities. Furthermore, responses to questionnaires in Study 3 revealed that older rural drivers reported being able to avoid difficult driving situations, reduce the amount that they drive, and were equally willing to stop driving as older urban drivers. This suggests that older rural drivers are able to maintain autonomous driving lifestyles. They have control of their driving choices and are unaffected by the circumstances of living in rural areas. These findings are positive, given how important driving mobility is to the health and well-being of older adults (Adler, et al., 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Edwards, et al.,

2009; Fonda, et al., 2001; Langford & Koppel, 2006a; Lister, 1999; Marottoli, et al., 2000; Marottoli, Mendes de Leon, et al., 1997; Mezuk & Rebok, 2008; Peel, et al., 2002; Whitehead, et al., 2006).

Recommendations to maintain mobility.

It is important that the level of mobility of both rural and urban older drivers is maintained. Despite the increased likelihood that older drivers, particularly those from rural areas, will be seriously or fatally injured if they are involved in a crash, they should be encouraged to continue driving for as long as they are able to do so safely. Thus, the challenge is to ensure that they do not stop driving prematurely.

At the time of writing, some licensing jurisdictions in Australia (e.g. New South Wales, Tasmania, and Western Australia¹⁴) had mandatory age-based assessments of fitness-to-drive for the purposes of relicensing older drivers, while the state of Victoria did not (Charlton, et al., 2009; Langford, Fitzharris, Newstead, et al., 2004; Langford & Koppel, 2006a). Those jurisdictions that do require these assessments vary in terms of what is required and the age at which they are necessary. Such variations also exist within and between other countries in the world (Charlton, et al., 2009; Langford, et al., 2009; Langford & Koppel, 2006a). The assessments (e.g. medical assessments, on-road driving assessments) are used to differentiate those older drivers who are fit to drive from those who are not. However, they need to be able to do so reliably because, if an older person who is fit to drive is incorrectly identified as unfit, then they may be forced to reduce or stop driving and, therefore, lose their mobility.

Some of these relicensing procedures can also be intimidating for older adults. For example, an on-road test of driving may require older adults to drive in an unfamiliar car and on unfamiliar roads. They may be apprehensive of the test and this can influence their

¹⁴ At the end of 2013, the South Australian Government announced that mandatory age-based testing of fitness-to-drive would cease in South Australia.

decision to prematurely reduce or give up driving, rather than undertaking the assessment (Charlton, et al., 2009; Charlton, 2002; Hakamies-Blomqvist, et al., 1996; Kulikov, 2011; Langford & Koppel, 2006a; Oxley, et al., 2003). Consequently, some researchers argue that age-based testing may actually deter safer, more conscientious drivers from getting their licence renewed (Eberhard, 1996; Lange & McKnight, 1996). Furthermore, there is also a lack of evidence that these practices have any demonstrable road safety benefits in terms of reductions in crash rates. This is supported by numerous studies which have found that the crash rates of older drivers in jurisdictions that impose mandatory testing do not differ from otherwise comparable jurisdictions that do not impose it (Grabowski, et al., 2004; Hakamies-Blomqvist, et al., 1996; Langford, Bohensky, et al., 2008; Langford, Fitzharris, Koppel, et al., 2004; Langford, Fitzharris, Newstead, et al., 2004; Langford & Koppel, 2006a; Torpey, 1986).

In addition to the debate about the worth of mandatory age-based testing, there has also been a large amount of research concerned with the nature of fitness to drive testing, and whether it occurs at a mandated age or only when concerns are raised about an individual's functioning and likely driving capacity. Such research has focused on identifying the health, functional and cognitive abilities that decline with age and are related to a decreased ability to drive and an increased crash risk (Baldock, Berndt, & Mathias, 2008; Baldock, et al., 2006b; Bunce, et al., 2012; Janke, 2001; Lesikar, et al., 2002; Lyman, et al., 2001; McGwin Jr, et al., 2000; Owsley, et al., 1999; Rizzo, et al., 2001; Vernon, et al., 2002; Wood, 2002a, 2002b; Wood & Carberry, 2006). It has been argued that measures of these abilities could be included in a comprehensive multi-tiered battery of tests to determine fitness-to-drive, with those individuals who are found to have significant health, cognitive or functional impairments having to undertake more expensive on-road fitness-to-drive assessments (Langford, Braitman, et al., 2008; McKenna, et al., 2004; Niewoehner, et al., 2012). However, there are many different measures of these abilities that have been developed (Mathias &

Lucas, 2009) and the research findings have been inconsistent regarding which measures have strong predictive validity in terms of driving ability (Bedard, et al., 2008). Research has also found that a range of leading screening measures was unable to distinguish between safe (non-crash involved) and unsafe (crash involved) older drivers (Langford, et al., 2009).

Consequently, there is currently no consensus in terms of what measure, or combination of measures, is the best option when screening potentially unsafe older drivers (Carr & Ott, 2010; Mathias & Lucas, 2009). If mandatory age-based testing is to be retained or implemented, the procedures need to have a demonstrable road safety benefit and, ideally, not be daunting for medically fit drivers who are required to undertake them. If this cannot be achieved, then consideration should be given to whether the use of mandatory fitness-to-drive assessments is justified. Also, as mentioned earlier, if mandatory age-based testing is to be retained or implemented, the present research and that by Classen et al. (2013) suggest that an appropriate age should be no younger than 75. It should also be noted that mandatory age-based testing may be difficult to implement in rural areas due to the remoteness of many of the locations and the costs that would be involved.

For those older adults who have to reduce or cease driving (e.g. due to declining health or cognitive or functional abilities), it is important that they are able to maintain a desirable level of mobility without relying on the use of a personal motor vehicle. However, Study 3 showed that the availability of public transportation and other alternatives to older adults in rural areas is limited. This is consistent with other previous studies (Adler, et al., 1999; Corcoran, et al., 2005; Johnson, 1995; Mattson, 2011; NCD, 2005; Nutley, 2003; Rosenbloom, 2004). Without alternative options, the cessation of driving would be likely to have a marked negative impact on older adults' health, well-being, lifestyles and community-connectedness; particularly because, as was shown in Study 3, driving is more important to older rural drivers than to older urban drivers.

Public transportation services (e.g. buses, trains) could be increased in rural areas and private services (e.g. taxis) could be subsidised in order to increase the availability of alternative transportation. While it may be possible to increase public transport options in large rural communities, the cost may make it impossible in smaller communities. A better option for smaller communities may be to encourage local councils, as well as independent groups, such as churches and senior citizens clubs, to increase their provision of community-run transportation (e.g. community buses that transport people to organised destinations or volunteer driver systems). These services are convenient and encourage community involvement. Indeed, it has been shown that older adults who use such services report a high level of satisfaction with them (Eby et al., 2012; Kostyniuk & Shope, 2003). Another option would be to implement a system in rural areas that is similar to that provided in the USA by the Independent Transport Network America organisation (<http://itnamerica.org/>). This system involves volunteer older drivers providing transportation for other older adults in their community who have ceased driving. These volunteers are given credits for their service, which can be used when they no longer drive themselves and need to be driven around.

Past research (Harris, 2002; Kostyniuk & Shope, 2003; Peel, et al., 2002; Rudman, et al., 2006; Silverstein, 2008; Stutts, et al., 2001) has indicated that older drivers do not plan for how they will meet their mobility needs if the time comes when they can no longer drive. This would increase the difficulty of transitioning from a driver to a non-driver. Moreover, it would make the transition particularly difficult for older rural drivers because of the limited availability of alternative transportation in rural areas and the long distances that they have to travel to access necessary services. Community leaders, health professionals, friends and family should encourage and assist older drivers to plan for when they can no longer drive (Adler & Rottunda, 2006; Mullen & Bédard, 2009; Silverstein, 2008; Windsor & Anstey, 2006). Educational programs and resources on successful retirement from driving could also be used to assist them to plan for life without a personal motor vehicle. This process of

planning would help them to maintain a degree of mobility and, therefore, aid their transition to becoming a non-driver (Bauer, et al., 2003). Such assistance may include family, friends and professionals helping older adults to become aware of the alternative transportation options that are available in their community, planning their travel and the related expenses so that they can meet their mobility needs using these options, and helping them to become accustomed to using them (Adler & Rottunda, 2006; Mullen & Bédard, 2009; Windsor & Anstey, 2006). Furthermore, these advocates could also assist in establishing more alternative options in rural areas (e.g. organising a carpooling system with others in the community).

Driving self-regulation by older rural adults.

One way in which older adults can both prolong their driving mobility and also potentially reduce their crash risk is by self-regulating their driving behaviour (Berry, 2011; D'Ambrosio, et al., 2008; Okonkwo, et al., 2008; Stalvey & Owsley, 2000). This can involve older drivers continuing to drive but increasing their avoidance of difficult or risky driving situations or reducing the overall amount of driving that they do. This practice may be particularly beneficial for older rural drivers. However, it has previously been shown that people who live in rural areas are more reliant on driving (Mattson, 2013; Nutley, 2003), that alternative transportation is limited in these areas (Adler, et al., 1999; Corcoran, et al., 2005; Johnson, 1995; Mattson, 2011; NCD, 2005; Nutley, 2003; Rosenbloom, 2004), and that adequate alternative transportation is needed for older adults to voluntarily reduce or avoid driving (Choi, et al., 2013; Stalvey & Owsley, 2000). Therefore, it was thought that older rural adults may find it more difficult to self-regulate their driving because of the importance they attribute to driving and the reduced access to alternative transportation in rural areas.

Indeed, Study 3 found that the older rural participants viewed their driving as more important than the older urban participants, believed that they had less public transport available to them, used public transport less, and had fewer other alternative means of

transportation (e.g. taxis) available to them. However, the two groups did not differ in their avoidance of difficult driving situations or the extent to which they had reduced the amount that they drove over the previous year. Thus, the older rural drivers were able to self-regulate to a similar degree as older urban drivers and were not restricted in doing so by the greater importance they place on driving or the limited alternative transportation available to them. The difficult driving situations that were most commonly avoided by both the rural and urban participants were parallel parking, driving at peak hour, driving at night and driving at night in the rain, while driving alone was the least commonly avoided. This corresponds closely with other research from South Australia by Baldock et al. (2006a). Given the importance of driving to older rural drivers and the limited alternative transportation, it was also thought that they may be less willing to stop driving if they were faced with reasons to do so. However, they were just as willing as older urban drivers to stop driving. Indeed, both the rural and urban participants reported a high willingness to stop driving. Therefore, it is a positive finding that older rural drivers are able to make choices about their driving and are not restricted in doing so by the circumstances of living in rural areas. However, it should be acknowledged that when older drivers reduce or change their driving patterns it is not always a conscious decision in response to an awareness of their risk on the road or their deteriorating abilities (Kowalski, Jeznach, & Tuokko, 2014), it may also be due to a general change in lifestyle (e.g. retiring from work and not needing to drive as much).

It should also be noted that the degree of avoidance of difficult driving situations and the reductions in the amount of driving over the past year by both the rural and urban participants was low. Indeed, the majority of the participants indicated that they “never” or “rarely” avoided the difficult driving situations and around half of the participants reporting that they had not reduced their driving. As a result, the variability in the scores for these measures was reduced, which made it difficult to detect a statistically significant difference in self-regulation between the rural and urban groups. The low scores may have resulted from

limitations in the measures that were used or from having a healthy sample who may not have needed to self-regulate (these issues are further discussed in the limitations section), but they may also accurately record the low level of self-regulation that is practised by most older drivers. The low level of self-regulation reported in the present study is consistent with previous research using the same self-report measure of avoidance of difficult driving situations (Baldock, et al., 2006a; Baldock, et al., 2006b; Stalvey & Owsley, 2000; Sullivan, et al., 2011). If it is an accurate measure of the extent of self-regulation by older drivers in the community, it has implications for older driver safety and mobility. A low level of self-regulation by older drivers in rural areas, where the risk of serious or fatal injuries is much higher for those who crash, means that there could be gains in older driver safety if more rural older drivers practised greater avoidance of difficult driving situations. Thus, educational programs which teach the benefits of self-regulation could be provided to older drivers who live in rural areas. The risky driving situations to avoid could include several of the environmental factors that were identified in Study 2 as increasing the likelihood of serious or fatal injury following a crash (e.g. undivided and unsealed roads, and areas with a speed limit of 100km/h or greater). Previous research (Owsley, et al., 2004; Owsley, et al., 2003) has shown that older drivers can be trained to increase their avoidance of driving situations through educational interventions. However, it is important to ensure that the ability of older rural drivers to reach necessary destinations is not affected by encouraging them to avoid these aspects of the driving environment.

Methodological Strengths of this Research

A key methodological strength of this research was the database of police-reported road crashes in South Australia, the Traffic Accident Reporting System (TARS), that was used in Studies 1 and 2. This database allowed an examination of all police-reported road crashes that occurred in South Australia over a five-year period (2004 to 2008). This database

includes specific details relating to the crashes, such as the nature, cause, time and location of the crash, and details of all drivers and any injured occupants or pedestrians who were involved in the crash. This meant that a detailed examination of the environmental, driver and vehicle factors that were involved in the crashes of rural and urban older drivers could be undertaken in Study 2. Furthermore, the TARS database is particularly useful because, as well as crashes in which people are injured, it records crashes where there is only property damage; thereby providing a comprehensive picture of overall crash involvement. Most police-reported crash databases do not include property damage crashes, which, given the susceptibility to injury of older vehicle occupants, means that they tend to overestimate older driver crashes because of the injury criterion for inclusion in the database. The tendency to overestimate older driver crash rates because of their susceptibility to injury is referred to as the ‘fragility bias’. By using the TARS database, it was hoped that any possible effects of the fragility bias on the examinations of the crash, serious injury, and fatality rates of older drivers in Studies 1 and 2 would have been reduced.

Another key methodological strength of this research was the use of GPS technology to accurately and objectively measure individuals’ driving exposure and travel patterns. This technology allowed a precise examination of the amount of driving that the participants undertook, the speeds that they drove at, the routes that they took, the number and type of intersections that they drove through, and the date and times that they drove. GPS-based measurements of driving exposure do not have the limitations of self-report methods, such as inaccurate reporting of standard exposure information (e.g. distance, time and number of trips), and have the ability to provide more complex exposure information (e.g. travelling speed and driving routes). In this way, this research and other contemporary studies (Blanchard, et al., 2010; Shoval et al., 2010) demonstrate the benefits of using this technology. However, GPS-based methods have limitations too, including the inability to identify the driver of a vehicle or the purpose of a trip. Self-report methods can provide this

information and, therefore, this research combined data obtained using both in-vehicle and self-report methods to provide the clearest picture of driving exposure and travel patterns. Both methods have also been used together in research by Blanchard et al. (2010). Thus, this suggests that GPS technology may not completely replace traditional self-report methods but is able to complement them.

In addition, the telephone-based Travel Diary that was used in the present study to obtain self-report information relating to driver identification and trip purpose was developed with the intention of reducing the burden on the individual volunteering for the study. This was important because traditional self-report methods require considerable effort on the part of the participant. For example, with self-administered travel diaries, the participant is required to complete detailed logs of their driving every day over a specified time period, which can be an onerous task. This may result in the participant forgetting to fill in the diary or filling it in at the last minute with incorrect information, and it also increases the likelihood of fatigue and non-compliance, all of which result in a loss of data (Marshall et al., 2007). It was anticipated that the demands on the participant, and the extent of resulting data loss, would be minimised with the Travel Diary because the researcher recorded the information rather than the participant. Indeed, when the trips that were recorded by GPS were matched to those reported by the participants in the Travel Diary, it was found that the majority were reported. Therefore, this method resulted in minimal data loss. Furthermore, the participants reported that they were not bothered by being called up each day and having to report their driving. This indicated that the method did not inconvenience the participants and was favourable to them. Thus, the telephone-based method, which to the best of the author's knowledge has not been used previously in research measuring driving exposure and travel patterns, has advantages over self-administered travel diaries and represents a methodological strength of the current research.

Limitations and Future Directions

Various limitations were acknowledged in the individual papers that comprise this thesis. However, when this research is considered in its entirety, it is worth re-visiting the limitations in the sample that was recruited for Studies 3, 4 and 5. Firstly, the rural participants were recruited from areas in South Australia that were relatively close to the capital city (i.e. within approximately two hours driving distance). Older drivers from more remote areas of the state could not be recruited for practical reasons, as the researcher was unable to routinely travel the distances required to recruit participants and collect data. People residing in these areas are likely to have to drive further to reach their destinations and, therefore, may have an even higher level of exposure to roads with high-speed limits. The need to drive further distances may also lead to their mobility being more restricted. Furthermore, their driving is likely to be even more important and their access to alternative transportation more limited, which may make it even harder for them to self-regulate their driving. Thus, the differences between the rural and urban participants in the various comparisons presented in Studies 3 and 5 may have been larger if people from remote areas were included. Therefore, the absence of remote participants in Studies 3 and 5 restricted the investigation of the overall aim of this thesis, which was to examine the safety and mobility of older drivers who live in rural or remote areas of South Australia in comparison to their urban counterparts. As it stands, only Studies 1 and 2 were able to provide any insights into the circumstances of remote older drivers because the TARS database includes road crashes that occur in all areas of South Australia. These studies provide insights into the safety of older drivers in different regions but not their mobility. The findings of Studies 3 and 5, designed to examine mobility in addition to safety issues, cannot be generalised to remote older drivers or how their circumstances compare to older urban drivers. If it is possible, older drivers from remote areas should be recruited in any future research on this topic.

The sample was also limited because the participants were recruited from senior citizens clubs and churches. Attendees at such community establishments, and particularly those willing to volunteer for the study, may be healthier and more active than other persons of the same age. Indeed, their ability to travel from their homes to these organisations suggests that they are amongst the more mobile older persons. Therefore, these rural participants may not have been discouraged by travelling longer distances because they were relatively healthy and mobile. This may explain why they were not restricted in the number of trips that they made or in their activities over the study period. Also, the degree to which older drivers self-regulate has been shown to be associated with their health, medical conditions and certain functional and cognitive abilities (Baldock, et al., 2006b; Ball, et al., 1998; Charlton, et al., 2006; Owsley, et al., 1999). The participants in the present study may not have needed to self-regulate as much because they were healthy and highly functioning. This could not be confirmed as these variables were not measured in this research. Future research should therefore assess the health and functional and cognitive ability of the sample, and endeavour to include participants who vary in their health, abilities or mobility. With respect to the self-selected nature of the sample, and the volunteer bias that this possibly introduced, it was noted previously that this is an issue that is difficult to overcome. Indeed, previous studies (Lee, Cameron, & Lee, 2003; Molnar, Charlton, et al., 2013) have suggested that volunteer bias in driving studies is inevitable because a truly random and representative sample would necessitate mandatory participation, which is neither possible nor desirable.

It should also be acknowledged that the convenience sample was recruited from a driving safety presentation specifically tailored to older adults and may have led to a degree of bias in the sample. Older adults who are conscientious enough to attend such a presentation may be more attuned and concerned about their driving safety and, therefore, may not be representative of all older drivers. Moreover, as they attended the presentation prior to participating in the study, the issue of driving safety may have been fresh in their minds. As a

result, it may have been expected that they would report a high degree of self-regulation in Study 3 in order to portray themselves as safe drivers. However, the reported levels of self-regulation were low. It might also have been expected that they would attempt to drive more slowly in Study 5. However, any such effects would have been equivalent across the rural and urban groups and the difference between them in terms of the amount that they drove at GPS-measured speeds of 100 km/h or faster was large. Therefore, it is unlikely that such sample bias had any substantial effects on the outcomes of this thesis.

Furthermore, the sample that was recruited for this research was small. In particular, only 56 individuals participated in Studies 4 and 5. Many participants who completed the questionnaire (Study 3) were unwilling to commit to the increased demands of a week of data collection that was required for Study 5. Nevertheless, the significant findings in Study 5, particularly in relation to the participants' exposure to risk, were characterised by low *p*-values of $< .001$. Thus, the sample size was sufficient for these analyses. In addition, the non-significant results were far from significant at the $p < .05$ level, which suggests that additional participants would not have changed these results.

The present research did not investigate how older drivers, rural or urban, are affected by driving cessation. This issue is important because, as mentioned throughout this research, the mobility that driving provides to older drivers is important for their independence and convenience, and to maintain an active lifestyle (Adler, et al., 1999; De Raedt & Ponjaert-Kristoffersen, 2000; Marottoli, et al., 2000; Peel, et al., 2002; Whitehead, et al., 2006). Moreover, a loss of mobility through driving cessation can lead to depression (Fonda, et al., 2001; Marottoli, Mendes de Leon, et al., 1997; Ragland, et al., 2005; Windsor, et al., 2007), a reduced network of friends (Mezuk & Rebok, 2008) and an increased risk of mortality over a 3-year period (Edwards, et al., 2009). However, the effects of driving cessation may be even greater for older drivers from rural or remote areas because they are more dependent on the ability to drive to meet their mobility requirements. Consistent with this, Study 3 found that

older rural drivers viewed their driving as more important than older urban drivers did and believed that they had fewer alternative means of transportation available to them.

Furthermore, Study 5 found that older rural drivers had to travel further distances to reach their destinations, which may further increase the importance of their personal vehicles.

Previous research in the USA by Johnson (1995) found that driving cessation caused feelings of isolation in older rural adults. Furthermore, older rural drivers in Canada who participated in research by Hanson and Hildebrand (2011c) reported that they would no longer undertake 36% of their usual trips if they did not have access to a vehicle. A comprehensive examination of this issue should be undertaken in the Australian rural/urban context. Ex-drivers from rural and urban areas could be recruited and compared in terms of the effects that driving cessation had on their lives. This could include the effects on their health, well-being, mobility, lifestyle, independence, depression, isolation and mortality. Such research could determine whether the effects of driving cessation are more pronounced for older rural drivers.

Another limitation of this research is the use of self-report methods to measure avoidance of difficult driving situations (as an index of self-regulation) in Study 3. As mentioned earlier, self-report measures of driving exposure and patterns can be unreliable as the participants may report inaccurate information (Blanchard, et al., 2010; Huebner, et al., 2006; Molnar, Charlton, et al., 2013; Staplin, et al., 2008; Staplin, Gish, & Wagner, 2003).

Three recent studies (Blanchard, et al., 2010; Hanson & Hildebrand, 2011a; Molnar, Charlton, et al., 2013) have used in-vehicle recording devices (with GPS technology) to measure the extent to which older drivers actually avoid difficult driving situations, compared to the degree to which they report doing so. Both Blanchard et al. (2010) and Molnar et al. (2013) found high levels of correspondence between the objective and subjective measures for specific difficult driving situations (e.g. driving at night, driving on high-speed roads/freeways), but there was also a lack of correspondence for other situations (e.g. making

unprotected turns across oncoming traffic). The Blanchard et al. (2010) study concluded that their participants did not self-regulate as much as they reported. However, Hanson and Hildebrand (2011a) found that, while approximately 10% of the participants in their sample of older rural drivers reported avoiding night driving, more than 50% actually did. They also found that, around 20% of the participants reported avoiding driving on major highways, but approximately 40% actually drove less than one per cent of their total surveyed kilometres on major highways. Thus, these studies highlight the limitations of using self-report methods to measure driving self-regulation. In Study 3, such inaccuracies may have affected the results relating to the comparison between self-regulation of rural and urban older drivers.

The self-report scale of avoidance of difficult driving situations that was used in Study 3 has also been widely used in previous research on older drivers to measure self-regulation (Baldock, et al., 2006a; Baldock, et al., 2006b; Baldock, Thompson, et al., 2008; Stalvey & Owsley, 2000). This scale was chosen so that the current findings, which compared the self-regulatory behaviour of rural and urban older drivers, - a topic that is new to the literature - were directly comparable to most of the previous research on self-regulation by older drivers. However, future research comparing the self-regulatory behaviour of rural and urban older drivers may benefit from the use of the objective and more accurate measurements that would be obtainable with GPS-based methods.

A final issue that is worth mentioning is that, given the longer distances that older rural drivers have to travel, they may have more of a desire to reduce their travel times than older urban drivers. Consequently, they may undertake more driving where they are travelling at speeds in excess of sign-posted speed limits and this may contribute to their increased likelihood of serious or fatal injury when they crash. Indeed, research by Gonzalez et al. (2007) examined crash incidents over a two-year period for drivers of all ages from both rural and urban areas of Alabama, USA. It was found that speeding contributed to an increased mortality rate for crashes in both rural and urban settings, but occurred more frequently in

crashes in rural settings. This issue was not examined in the present set of studies, but could be considered for future research. In particular, the use of GPS-measured driving exposure and GIS mapping software would allow a comparison of rural and urban older drivers in terms of the extent to which they travel in excess of the speed limit. As demonstrated in the current research (Study 5), a person's GPS-recorded driving can be matched to the roads on which the driving took place and information about the roads (i.e. sign-posted speed limits) can be recorded. It could then be determined whether the travelling speed of the vehicle was above the speed limit for each section of road that a person drove on.

Final Conclusions

Overall, this research demonstrates that living in rural areas affects the driving safety of older adults, in that the rural driving environment increases the likelihood that they will be seriously or fatally injured if they are involved in a crash. Therefore, older adults who live and drive in rural areas are a section of the older community who deserve particular attention from the standpoint of road safety research and policy. Fortunately, however, their day-to-day driving mobility is not affected by living in rural areas, in that they undertake as much driving and as many activities through their driving, as older urban drivers. The challenge for public policy now is to reduce the risk of serious and fatal injury for older rural drivers without affecting their mobility in the process. Safe and sustainable mobility would be an ideal outcome for older rural drivers. This research does suggest some means to improve their safety that would not affect their mobility. These include modifying the rural driving environment (e.g. decreasing speed limits) and encouraging the use of newer vehicles, which provide better protection in a crash.

References¹⁵

- Adler, G., Bauer, M., Rottunda, S., & Kuskowski, M. (2005). Driving habits and patterns in older men with glaucoma. *Social Work in Health Care, 40*(3), 75-87. doi: 10.1300/J010v40n03_05
- Adler, G., & Rottunda, S. (2006). Older adults' perspectives on driving cessation. *Journal of Aging Studies, 20*(3), 227-235. doi: 10.1016/j.jaging.2005.09.003
- Adler, G., Rottunda, S., & Kuskowski, M. (1999). Dementia and driving: Perceptions and changing habits. *Clinical Gerontologist, 20*(2), 23-35. doi: 10.1300/J018v20n02_03
- Alvarez, F. J., & Fierro, I. (2008). Older drivers, medical condition, medical impairment and crash risk. *Accident Analysis and Prevention, 40*(1), 55-60. doi: 10.1016/j.aap.2007.04.001
- Amosun, S. L., Burgess, T., Groeneveldt, L., & Hodgson, T. (2007). Are elderly pedestrians allowed enough time at pedestrian crossings in Cape Town, South Africa? *Physiotherapy Theory and Practice, 23*(6), 325-332. doi: 10.1080/09593980701593755
- Anderson, R., Anstey, K. J., & Wood, J. (2009). The right approach for older drivers. *Journal of the Australasian College of Road Safety, 20*(3), 37-39. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-20-No3Website1.pdf>
- Anderson, R. W. G., & Doecke, S. (2010). The relative age related crashworthiness of the registered South Australian passenger vehicle fleet. *Journal of the Australasian College of Road Safety, 21*(1), 36-46. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-21-1-Web1.pdf>
- Anderson, R. W. G., & Hutchinson, T. P. (2010). *In Australia, is injury less in recent cars than in earlier cars? Evidence from comparing the injury severities of two drivers in*

¹⁵ Listed references are for Chapters 1, 2 and 8, Chapter Preambles, and Footnotes.

- the same collision.* Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra, Australian Capital Territory. Retrieved from <http://acrs.org.au/files/arsrpe/R2010706.pdf>
- Anderson, R. W. G., Hutchinson, T. P., Linke, B., & Ponte, G. (2011). *Analysis of crash data to estimate the benefits of emerging vehicle technology* (Report No. CASR094). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://casr.adelaide.edu.au/casrpublish/show.php?id=1217>
- Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review*, 25(1), 45-65. doi: 10.1016/j.cpr.2004.07.008
- APA. (2010). *Publication manual of the American Psychological Association* (6th ed.). Washington, DC: American Psychological Association.
- Archer, J., Fotheringham, N., Symmons, M., & Corben, B. (2008). *The impact of lowered speed limits in urban and metropolitan areas* (Report No. 276). Clayton: Monash University Accident Research Centre. Retrieved from <http://www.monash.edu.au/miri/research/reports/muarc276.pdf>
- Asher, L., Aresu, M., Falaschetti, E., & Mindell, J. (2012). Most older pedestrians are unable to cross the road in time: A cross-sectional study. *Age and Ageing*, 41(5), 690-694. doi: 10.1093/ageing/afs076
- Baldock, M. R. J. (2004). *Self-Regulation of the Driving Behaviour of Older Drivers* (Doctoral thesis, University of Adelaide, Adelaide, Australia). Retrieved from <http://digital.library.adelaide.edu.au/dspace/handle/2440/37930>
- Baldock, M. R. J., Berndt, A., & Mathias, J. L. (2008). The functional correlates of older drivers' on-road driving test errors. *Topics in Geriatric Rehabilitation*, 24(3), 204-223. doi: 10.1097/TGR.0000333754.90550.b5

Baldock, M. R. J., Kloeden, C. N., & McLean, A. J. (2008). *In-depth research into rural road crashes* (Report No. CASR057). Adelaide: Centre for Automotive Safety Research.

Retrieved from

<http://digital.library.adelaide.edu.au/dspace/bitstream/2440/50534/1/CASR057.pdf>

Baldock, M. R. J., Mathias, J. L., McLean, A. J., & Berndt, A. (2006a). Self-regulation of driving and its relationship to driving ability among older adults. *Accident Analysis and Prevention*, 38, 1038-1045. doi: 10.1016/j.aap.2006.04.016

Baldock, M. R. J., Mathias, J. L., McLean, J., & Berndt, A. (2006b). Self-regulation of driving and older drivers' functional abilities. *Clinical Gerontologist*, 30(1), 53-70. doi: 10.1300/J018v30n01_05

Baldock, M. R. J., & McLean, A. J. (2005). *Older drivers: Crash involvement rates and causes* (Report No. CASR015). Adelaide: Centre for Automotive Safety Research.

Retrieved from

<http://digital.library.adelaide.edu.au/dspace/bitstream/2440/36418/1/CASR015.pdf>

Baldock, M. R. J., Thompson, J. P., & Mathias, J. L. (2008). *Self-regulation of driving behaviour among older drivers: Findings from a five year follow-up*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Adelaide, South Australia. Retrieved from

<http://acrs.org.au/files/arsrpe/RS080117.pdf>

Ball, K., & Owsley, C. (2003). Driving competence: It's not a matter of age. *Journal of the American Geriatrics Society*, 51(10), 1499-1501. doi: 10.1046/j.1532-5415.2003.51487.x

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science*, 34(11), 3110-3123. Retrieved from <http://www.iovs.org/content/34/11/3110.full.pdf+html>

- Ball, K., Owsley, C., Stalvey, B., Roenker, D. L., Sloane, M. E., & Graves, M. (1998). Driving avoidance and functional impairment in older drivers. *Accident Analysis and Prevention*, 30(3), 313-322. doi: 10.1016/S0001-4575(97)00102-4
- Ball, K. K., Roenker, D. L., Wadley, V. G., Edwards, J. D., Roth, D. L., McGwin Jr, G., . . . Cissell, G. M. (2006). Can high-risk older drivers be identified through performance-based measures in a Department of Motor Vehicles setting? *Journal of the American Geriatrics Society*, 54(1), 77-84. doi: 10.1111/j.1532-5415.2005.00568.x
- Bauer, M. J., Rottunda, S., & Adler, G. (2003). Older women and driving cessation. *Qualitative Social Work*, 2(3), 309-325. doi: 10.1177/14733250030023006
- Baum, H. M., Wells, J. K., & Lund, A. K. (1990). Motor vehicle crash fatalities in the second year of 65 mph speed limits. *Journal of Safety Research*, 21(1), 1-8. doi: 10.1016/0022-4375(90)90042-A
- Bedard, M., Weaver, B., Darzins, P., & Porter, M. M. (2008). Predicting driving performance in older adults: We are not there yet! *Traffic Injury Prevention*, 9(4), 336-341. doi: 10.1080/15389580802117184
- Begg, D. J., Langley, J. D., & Williams, S. M. (1999). Validity of self reported crashes and injuries in a longitudinal study of young adults. *Injury Prevention*, 5(2), 142-144. doi: 10.1136/ip.5.2.142
- Bentham, G. (1986). Proximity to hospital and mortality from motor vehicle traffic accidents. *Social Science and Medicine*, 23(10), 1021-1026. doi: 10.1016/0277-9536(86)90260-1
- Berry, C. (2011). *Can older drivers be nudged? How the public and private sectors can influence older drivers' self-regulation*. London: RAC Foundation. Retrieved from http://www.racfoundation.org/assets/rac_foundation/content/downloadables/older_drivers_nudge-main_report-berry.pdf

- Betz, M. E., Jones, J., Petroff, E., & Schwartz, R. (2013). "I wish we could normalize driving health:" A qualitative study of clinician discussions with older drivers. *Journal of General Internal Medicine*, 28(12), 1573-1580. doi: 10.1007/s11606-013-2498-x
- Blanchard, R. A., Myers, A. M., & Porter, M. M. (2010). Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. *Accident Analysis and Prevention*, 42(2), 523-529. doi: 10.1016/j.aap.2009.09.018
- Bonnel, W. B. (1999). Giving up the car: Older women's losses and experiences. *Journal of Psychosocial Nursing and Mental Health Services*, 37(5), 10-15. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10340225>
- Booth, H., & Tickle, L. (2003). The future aged: New projections of Australia's elderly population. *Australasian Journal on Ageing*, 22(4), 196-202. doi: 10.1111/j.1741-6612.2003.tb00497.x
- Borgialli, D. A., Hill, E. M., Maio, R. F., Compton, C. P., & Gregor, M. A. (2000). Effects of alcohol on the geographic variation of driver fatalities in motor vehicle crashes. *Academic Emergency Medicine*, 7(1), 7-13. doi: 10.1111/j.1553-2712.2000.tb01882.x
- Boshoff, K., & Hartshorne, S. (2008). Profile of occupational therapy practice in rural and remote South Australia. *Australian Journal of Rural Health*, 16(5), 255-261. doi: 10.1111/j.1440-1584.2008.00988.x
- Boufous, S., Finch, C., Hayen, A., & Williamson, A. (2008). The impact of environmental, vehicle and driver characteristics on injury severity in older drivers hospitalized as a result of a traffic crash. *Journal of Safety Research*, 39(1), 65-72. doi: 10.1016/j.jsr.2007.10.010
- Braitman, K. A., Kirley, B. B., Ferguson, S., & Chaudhary, N. K. (2007). Factors leading to older drivers' intersection crashes. *Traffic Injury Prevention*, 8(3), 267-274. doi: 10.1080/15389580701272346

- Braitman, K. A., & Williams, A. F. (2011). Changes in self-regulatory driving among older drivers over time. *Traffic Injury Prevention*, 12(6), 568-575. doi: 10.1080/15389588.2011.616249
- Brand, S., Otte, D., Mueller, C. W., Petri, M., Haas, P., Stuebig, T., . . . Haasper, C. (2012). Injury patterns of seniors in traffic accidents: A technical and medical analysis. *World Journal of Orthopedics*, 3(9), 151-155. doi: 10.5312/wjo.v3.i9.151
- Bricka, S. G., Sen, S., Paleti, R., & Bhat, C. R. (2012). An analysis of the factors influencing differences in survey-reported and GPS-recorded trips. *Transportation Research Part C*, 21, 67-88. doi: 10.1016/j.trc.2011.09.005
- Brodsky, H., & Shalom Hakkert, A. (1983). Highway fatal accidents and accessibility of emergency medical services. *Social Science and Medicine*, 17(11), 731-740. doi: 10.1016/0277-9536(83)90261-7
- Brouwer, W. H., Waterink, W., Van Wolffelaar, P. C., & Rothengatter, T. (1991). Divided attention in experienced young and older drivers: Lane tracking and visual analysis in a dynamic driving simulator. *Human Factors*, 33(5), 573-582. doi: 10.1177/001872089103300508
- Brown, L. H., Khanna, A., & Hunt, R. C. (2000). Rural vs urban motor vehicle crash death rates: 20 years of FARS data. *Prehospital Emergency Care*, 4(1), 7-13. doi: 10.1080/10903120090941551
- Bowers, A. R., Anastasio, R. J., Sheldon, S. S., O'Connor, M. G., Hollis, A. M., Howe, P. D., & Horowitz, T. S. (2013). Can we improve clinical prediction of at-risk older drivers? *Accident Analysis and Prevention*, 59, 537-547. doi: 10.1016/j.aap.2013.06.037
- Budd, L., Scully, M., Newstead, S. V., & Watson, L. (2012). *The potential crash and injury reduction benefits of safer vehicle choices for older drivers in Australia and New Zealand* (Report No. 315). Clayton, Victoria: Monash University Accident Research

Centre. Retrieved from

<http://www.monash.edu.au/miri/research/reports/muarc315.pdf>

Bunce, D., Young, M. S., Blane, A., & Khugputh, P. (2012). Age and inconsistency in driving performance. *Accident Analysis and Prevention*, 49, 293-299. doi: 10.1016/j.aap.2012.01.001

Burkhardt, J. E., & McGavock, A. T. (1999). Tomorrow's older drivers: Who? How many? What impacts? *Transportation Research Record: Journal of the Transportation Research Board*, 1693, 62-70. doi: 10.3141/1693-10

Burns, P. C. (1999). Navigation and the mobility of older drivers. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 54B(1), S49-S55. doi: 10.1093/geronb/54B.1.S49

Carr, D. B., & Ott, B. R. (2010). The older adult driver with cognitive impairment: "It's a very frustrating life". *Journal of the American Medical Association*, 303(16), 1632-1641. doi: 10.1001/jama.2010.481.

Catchpole, J., Styles, T., Pyta, V., & Imberger, K. (2005). *Exposure and accident risk among older drivers* (Report No. ARR 366). Victoria, Australia: ARRB Group Ltd. Retrieved from

http://arrb.com.au/admin/file/content13/c6/ARR366%20Accident%20risk_1282261803369.pdf

Champion, H. R., Augenstein, J., Blatt, A. J., Cushing, B., Digges, K., Siegel, J. H., & Flanigan, M. C. (2004). Automatic crash notification and the URGENCY algorithm: Its history, value, and use. *Topics in Emergency Medicine*, 26(2), 143-156. Retrieved from

http://journals.lww.com/aenjournal/Abstract/2004/04000/Automatic_Crash_Notify_on_and_the_URGENCY.9.aspx

- Charlton, J., Fildes, B., & Andrea, D. (2002). Vehicle safety and older occupants. *Gerontechnology*, 1(4), 274-286. doi: 10.4017/gt.2002.01.04.006.00
- Charlton, J., Koppel, S., Langford, J., & Irving, J. (2009). Managing older driver crash risk. In M. Odell (Ed.), *Older road users* (pp. 25-51). Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.
- Charlton, J. L. (2002). Licensing issues. In *Transcript of proceedings: Mobility and safety of older people conference, Melbourne, Victoria, August 2002* (pp. 45-65). Melbourne, Victoria: Australian College of Road Safety.
- Charlton, J. L., Koppel, S., Odell, M., Devlin, A., Langford, J., O'Hare, M., . . . Scully, M. (2010). *Influence of chronic illness on crash involvement of motor vehicle drivers: 2nd edition* (Report No. 300). Clayton: Monash University Accident Research Centre.
Retrieved from <http://www.monash.edu.au/miri/research/reports/muarc300.pdf>
- Charlton, J. L., Oxley, J., Fildes, B., Oxley, P., & Newstead, S. (2003). *Self-regulatory behaviours of older drivers*. Paper presented at the 47th Annual Proceedings: Association for the Advancement of Automotive Medicine, Lisbon, Portugal.
Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3217566/>
- Charlton, J. L., Oxley, J., Fildes, B., Oxley, P., Newstead, S., Koppel, S., & O'Hare, M. (2006). Characteristics of older drivers who adopt self-regulatory driving behaviours. *Transportation Research Part F*, 9(5), 363-373. doi: 10.1016/j.trf.2006.06.006
- Chen, B., Maio, R. F., Green, P. E., & Burney, R. E. (1995). Geographic variation in preventable deaths from motor vehicle crashes. *Journal of Trauma-Injury Infection and Critical Care*, 38(2), 228-232. Retrieved from http://journals.lww.com/jtrauma/Abstract/1995/02000/Geographic_Variation_in_Prev.aspx

- Cheung, I., & McCartt, A. T. (2011). Declines in fatal crashes of older drivers: Changes in crash risk and survivability. *Accident Analysis and Prevention*, 43(3), 666-674. doi: 10.1016/j.aap.2010.10.010
- Cheung, I., McCartt, A. T., & Braitman, K. A. (2008). Exploring the declines in older driver fatal crash involvement. In *Annals of Advances in Automotive Medicine/52nd Annual Scientific Conference, October 2008* (pp. 255-264). Association for the Advancement of Automotive Medicine. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3256784/>
- Choi, M., Adams, K. B., & Kahana, E. (2013). Self-regulatory driving behaviors: Gender and transportation support effects. *Journal of Women & Aging*, 25(2), 104-118. doi: 10.1080/08952841.2012.720212
- Cicchino, J. B., & McCartt, A. T. (2014). Trends in older driver crash involvement rates and survivability in the United States: An update. *Accident Analysis and Prevention*, 72, 44-54. doi: 10.1016/j.aap.2014.06.011
- Clark, D. E. (2003). Effect of population density on mortality after motor vehicle collisions. *Accident Analysis and Prevention*, 35(6), 965-971. doi: 10.1016/S0001-4575(02)00104-5
- Clark, D. E., & Cushing, B. M. (2002). Predicted effect of automatic crash notification on traffic mortality. *Accident Analysis and Prevention*, 34(4), 507-513. doi: 10.1016/S0001-4575(01)00048-3
- Clarke, D. D., Ward, P., Bartle, C., & Truman, W. (2010). Older drivers' road traffic crashes in the UK. *Accident Analysis and Prevention*, 42(4), 1018-1024. doi: 10.1016/j.aap.2009.12.005
- Classen, S., Wang, Y., Crizzle, A. M., Winter, S. M., & Lanford, D. N. (2013). Gender differences among older drivers in a comprehensive driving evaluation. *Accident Analysis and Prevention*, 61, 146-152. doi: 10.1016/j.aap.2012.10.010

- Collia, D. V., Sharp, J., & Giesbrecht, L. (2003). The 2001 national household travel survey: A look into the travel patterns of older Americans. *Journal of Safety Research*, 34(4), 461-470. doi: 10.1016/j.jsr.2003.10.001
- Connell, C. M., Harmon, A., Janevic, M. R., & Kostyniuk, L. P. (2013). Older adults' driving reduction and cessation: Perspectives of adult children. *Journal of Applied Gerontology*, 32(8), 975-996. doi: 10.1177/0733464812448962
- Cooper, L., Meulenens, L. B., Duke, J., Jancey, J., & Hildebrand, J. (2011). Psychotropic medications and crash risk in older drivers: A review of the literature. *Asia-Pacific Journal of Public Health*, 23(4), 443-457. doi: 10.1177/1010539511407661
- Cooper, P. J. (1990). Elderly drivers' views of self and driving in relation to the evidence of accident data. *Journal of Safety Research*, 21(3), 103-113. doi: 10.1016/0022-4375(90)90018-7
- Cooper, P. J., Tallman, K., Tuokko, H., & Beattie, B. L. (1993a). Safety-related driving performance changes in older drivers. *Journal of Traffic Medicine*, 21(1), 21-27. Retrieved from <http://trid.trb.org/view.aspx?id=383150>
- Cooper, P. J., Tallman, K., Tuokko, H., & Beattie, B. L. (1993b). Vehicle crash involvement and cognitive deficit in older drivers. *Journal of Safety Research*, 24(1), 9-17. doi: 10.1016/0022-4375(93)90047-Q
- Corcoran, S., James, E. L., & Ellis, J. M. (2005). Do elderly Victorians in rural areas have access to public transport? *Road & Transport Research*, 14(1), 38-43. Retrieved from <http://www.arrb.com.au/Information-services/Publications/Issue.aspx?id=39>
- Cotrell, V., & Wild, K. (1999). Longitudinal study of self-imposed driving restrictions and deficit awareness in patients with Alzheimer disease. *Alzheimer Disease and Associated Disorders*, 13(3), 151-156. Retrieved from http://journals.lww.com/alzheimerjournal/Abstract/1999/07000/Longitudinal_Study_of_Self_imposed_Driving.7.aspx

- Cushman, L. A. (1996). Cognitive capacity and concurrent driving performance in older drivers. *IATSS Research*, 20(1), 38-45. Retrieved from <http://trid.trb.org/view.aspx?id=481452>
- D'Ambrosio, L. A., Donorfio, L. K. M., Coughlin, J. F., Mohyde, M., & Meyer, J. (2008). Gender differences in self-regulation patterns and attitudes toward driving among older adults. *Journal of Women & Aging*, 20(3/4), 265-282. doi: 10.1080/08952840801984758
- Daigneault, G., Joly, P., & Frigon, J. Y. (2002a). Executive functions in the evaluation of accident risk of older drivers. *Journal of Clinical and Experimental Neuropsychology*, 24(2), 221-238. doi: 10.1076/jcen.24.2.221.993
- Daigneault, G., Joly, P., & Frigon, J. Y. (2002b). Previous convictions or accidents and the risk of subsequent accidents of older drivers. *Accident Analysis and Prevention*, 34(2), 257-261. doi: 10.1016/S0001-4575(01)00014-8
- Davey, J. A. (2007). Older people and transport: Coping without a car. *Ageing and Society*, 27(1), 49-65. doi: 10.1017/S0144686X06005332
- Dawson, J. D., Anderson, S. W., Uc, E. Y., Dastrup, E., & Rizzo, M. (2009). Predictors of driving safety in early Alzheimer disease. *Neurology*, 72(6), 521-527. doi: 10.1212/01.wnl.0000341931.35870.49
- De Raedt, R., & Ponjaert-Kristoffersen, I. (2000). The relationship between cognitive/neuropsychological factors and car driving performance in older adults. *Journal of the American Geriatrics Society*, 48(12), 1664-1668. Retrieved from <http://psycnet.apa.org/psycinfo/2000-12632-014>
- Decina, L. E., & Staplin, L. (1993). Retrospective evaluation of alternative vision screening criteria for older and younger drivers. *Accident Analysis and Prevention*, 25(3), 267-275. doi: 10.1016/0001-4575(93)90021-N

- Dellinger, A. M., Langlois, J. A., & Li, G. (2002). Fatal crashes among older drivers: Decomposition of rates into contributing factors. *American Journal of Epidemiology*, 155(3), 234-241. doi: 10.1093/aje/155.3.234
- Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bedard, M., Berg-Weger, M., . . . Trujillo, L. (2007). Transportation and aging: A research agenda for advancing safe mobility. *The Gerontologist*, 47(5), 578-590. doi: 10.1093/geront/47.5.578
- Dommes, A., & Cavallo, V. (2011). The role of perceptual, cognitive, and motor abilities in street-crossing decisions of young and older pedestrians. *Ophthalmic and Physiological Optics*, 31(3), 292-301. doi: 10.1111/j.1475-1313.2011.00835.x
- Donaldson, A. E., Cook, L. J., Hutchings, C. B., & Dean, J. M. (2006). Crossing county lines: The impact of crash location and driver's residence on motor vehicle crash fatality. *Accident Analysis and Prevention*, 38(4), 723-727. doi: 10.1016/j.aap.2006.01.002
- Dotzauer, M., Caljouw, S. R., de Waard, D., & Brouwer, W. H. (2013). Intersection assistance: A safe solution for older drivers? *Accident Analysis and Prevention*, 59, 522-528. doi: 10.1016/j.aap.2013.07.024
- Du, W., Finch, C., Hayen, A., & Hatfield, J. (2007). Differences in injury rates in child motor vehicle passengers in rural and urban areas in New South Wales, July 2000 to June 2004. *Australian and New Zealand Journal of Public Health*, 31(5), 483-488. doi: 10.1111/j.1753-6405.2007.00122.x
- Duchek, J. M., Carr, D. B., Hunt, L., Roe, C. M., Xiong, C., Shah, K., & Morris, J. C. (2003). Longitudinal driving performance in early-stage dementia of the Alzheimer type. *Journal of the American Geriatrics Society*, 51(10), 1342-1347. doi: 10.1046/j.1532-5415.2003.51481.x
- Duchek, J. M., Hunt, L., Ball, K., Buckles, V., & Morris, J. C. (1998). Attention and driving performance in Alzheimer's disease. *The Journals of Gerontology, Series B*:

Psychological Sciences and Social Sciences, 53B(2), P130-P141. doi:

10.1093/geronb/53B.2.P130

Dutschke, J. K., & Woolley, J. E. (2010). Simulation of rural travel times to quantify the impact of lower speed limits. *Journal of the Australasian College of Road Safety*, 21(1), 46-56. Retrieved from <http://acrs.org.au/wp-content/uploads/ACRS-Journal-21-1-Web1.pdf>

Eberhard, J. W. (1996). Safe mobility for senior citizens. *IATSS Research*, 20(1), 29-37.

Retrieved from <http://ntl.bts.gov/lib/25000/25900/25903/DOT-HS-EPX-040.pdf>

Eby, D. W., & Molnar, L. J. (2012). *Has the time come for an older driver vehicle?* (Report

No. UMTRI-2012-5). Ann Arbor: University of Michigan Transportation Research

Institute. Retrieved from

<http://deepblue.lib.umich.edu/bitstream/handle/2027.42/89960/102821.pdf?sequence=1>

Eby, D. W., Molnar, L. J., Kostyniuk, L. P., St. Louis, R. M., Zanier, N., & Kellman, D.

(2012). *Recommendations for meeting the mobility needs of older adults in rural*

Michigan (Report No. RC-1592). Michigan: The University of Michigan

Transportation Research Institute. Retrieved from

http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC1592_408044_7.pdf

Edwards, J. D., Perkins, M., Ross, L. A., & Reynolds, S. L. (2009). Driving status and three-

year mortality among community-dwelling older adults. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences*, 64A(2), 300-305. doi:

10.1093/gerona/gln019

Eisenhandler, S. A. (1990). The asphalt identikit: Old age and the driver's license. *The*

International Journal of Aging and Human Development, 30(1), 1-14. doi:

10.2190/0MF5-HQ1L-7EBY-XNXV

Elliott, D., Elliott, B., & Lysaght, A. (1995). *Older driver risks and countermeasures: Source book* (Report No. CR 163). Canberra, Australia: Federal Office of Road Safety.

Retrieved from

https://www.dotars.gov.au/roads/safety/publications/1995/pdf/Older_Risk_1.pdf

Elvik, R., Christensen, P., & Amundsen, A. (2004). *Speed and road accidents: An evaluation of the Power Model* (Report 740/2004). Oslo: Institute of Transport Economics.

Retrieved from

<https://www.toi.no/getfile.php/Publikasjoner/TØI%20rapporter/2004/740-2004.pdf>

Engeland, A., Skurtveit, S., & Mørland, J. (2007). Risk of road traffic accidents associated with the prescription of drugs: A registry-based cohort study. *Annals of Epidemiology*, 17(8), 597-602. doi: 10.1016/j.annepidem.2007.03.009

Etminan, M., Hemmelgarn, B., Delaney, J. A. C., & Suissa, S. (2004). Use of lithium and the risk of injurious motor vehicle crash in elderly adults: Case-control study nested within a cohort. *British Medical Journal*, 328, 558-559. doi: 10.1136/bmj.38002.514838.94

Evans, L. (1988). Risk of fatality from physical trauma versus sex and age. *The Journal of Trauma*, 28(3), 368-378. Retrieved from

http://journals.lww.com/jtrauma/Abstract/1988/03000/Risk_of_Fatality_from_Physical_Trauma_versus_Sex.13.aspx

Evans, L. (1993). How safe were today's older drivers when they were younger? *American Journal of Epidemiology*, 137(7), 769-775. Retrieved from
<http://aje.oxfordjournals.org/content/137/7/769.short>

Evans, L. (2000). Risks older drivers face themselves and threats they pose to other road users. *International Journal of Epidemiology*, 29(2), 315-322. doi: 10.1093/ije/29.2.315

- Evans, L. (2001). Age and fatality risk from similar severity impacts. *Journal of Traffic Medicine*, 29(1-2), 10-19. Retrieved from <http://www.scienceservingsociety.com/p/136.pdf>
- Festa, E. K., Ott, B. R., Manning, K. J., Davis, J. D., & Heindel, W. C. (2013). Effect of cognitive status on self-regulatory driving behavior in older adults: An assessment of naturalistic driving using in-car video recordings. *Journal of Geriatric Psychiatry and Neurology*, 26(1), 10-18. doi: 10.1177/0891988712473801
- Fildes, B. (2006). Older drivers' safety and mobility: Current and future issues. *Transportation Research Part F: Traffic Psychology and Behaviour*, 9(5), 307-308. doi: doi:10.1016/j.trf.2006.07.001
- Fildes, B., Fitzharris, M., Charlton, J., & Pronk, N. (2001). *Older driver safety - A challenge for Sweden's "Vision Zero"*. Paper presented at the Australian Transport Research Forum, Hobart, Australia. Retrieved from <http://trid.trb.org/view.aspx?id=712249>
- Fildes, B. N., Corben, B., Kent, S. M., Oxley, J., Le, T. M., & Ryan, P. (1994). *Older Road User Crashes: Driver, Pedestrian, Elderly, Injury, Crash Trends, Crash Characteristics, Road Trauma Costs, Countermeasures* (Report No. 61). Melbourne, Australia: Monash University Accident Research Centre. Retrieved from <http://www.monash.edu.au/miri/research/reports/muarc061.pdf>
- Finison, K. S., & Dubrow, R. B. (2002). *A comparison of Maine crashes involving older drivers* (Report No. HS-809 407). Washington, DC: National Highway Traffic Safety Administration. Retrieved from <http://trid.trb.org/view.aspx?id=718105>
- Fitten, L. J., Perryman, K. M., Wilkinson, C. J., Little, R. J., Burns, M. M., Pachana, N., . . . Ganzell, S. (1995). Alzheimer and vascular dementias and driving: A prospective road and laboratory study. *Journal of the American Medical Association*, 273(17), 1360-1365. doi: doi:10.1001/jama.1995.03520410054026

- Foley, D. J., Helmovitz, H. K., Guralnik, J. M., & Brock, D. B. (2002). Driving life expectancy of persons aged 70 years and older in the United States. *American Journal of Public Health, 92*(8), 1284-1289. doi: 10.2105/AJPH.92.8.1284
- Foley, D. J., Wallace, R. B., & Eberhard, J. (1995). Risk factors for motor vehicle crashes among older drivers in a rural community. *Journal of the American Geriatrics Society, 43*(7), 776-781. Retrieved from <http://europepmc.org/abstract/MED/7602030>
- Fonda, S. J., Wallace, R. B., & Herzog, A. R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *Journal of Gerontology: Social Sciences, 56B*(6), S343-S351. doi: 10.1093/geronb/56.6.S343
- Forrest, K. Y., Bunker, C. H., Songer, T. J., Coben, J. H., & Cauley, J. A. (1997). Driving patterns and medical conditions in older women. *Journal of the American Geriatrics Society, 45*(10), 1214-1218. Retrieved from <http://europepmc.org/abstract/MED/9329483>
- Freeman, E. E., Munoz, B., Turano, K. A., & West, S. K. (2005). Measures of visual function and their association with driving modification in older adults. *Investigative Ophthalmology and Visual Science, 47*(2), 514-520. doi: 10.1167/iovs.05-0934
- Freund, B., & Petrakos, D. (2008). Continued driving and time to transition to nondriver status through error-specific driving restrictions. *Gerontology and Geriatrics Education, 29*(4), 326-335. doi: 10.1080/02701960802497852
- Freund, B., & Szinovacz, M. (2002). Effects of cognition on driving involvement among the oldest old: Variations by gender and alternative transportation opportunities. *The Gerontologist, 42*(5), 621-633. doi: 10.1093/geront/42.5.621
- Friedland, R. P., Koss, E., Kumar, A., Gaine, S., Metzler, D., Haxby, J. V., & Moore, A. (1988). Motor vehicle crashes in dementia of the Alzheimer Type. *Annals of Neurology, 24*(6), 782-786. doi: 10.1002/ana.410240613

- Gallo, J. J., Rebok, G. W., & Lesikar, S. E. (1999). The driving habits of adults aged 60 years and older. *Journal of the American Geriatrics Society*, 47(3), 335-341. Retrieved from <http://psycnet.apa.org/psycinfo/1999-10561-006>
- Gay, J., Herriot, M., & May, A. (1995). Primary health care beyond the city. In F. Baum (Ed.), *Health for all: The South Australian experience* (pp. 375-392). Kent Town, South Australia: Wakefield Press.
- Gonzalez, R. P., Cummings, G. R., Phelan, H. A., Harlin, S., Mulekar, M., & Rodning, C. B. (2007). Increased rural vehicular mortality rates: Roadways with higher speed limits or excessive vehicular speed? *The Journal of Trauma*, 63(6), 1360-1363. doi: 10.1097/TA.0b013e31815b83b3
- Grabowski, D. C., Campbell, C. M., & Morrisey, M. A. (2004). Elderly licensure laws and motor vehicle fatalities. *Journal of the American Medical Association*, 291(23), 2840-2846. doi: 10.1001/jama.291.23.2840.
- Green, K. A., McGwin Jr, G., & Owsley, C. (2013). Associations between visual, hearing, and dual sensory impairments and history of motor vehicle collision involvement of older drivers. *Journal of the American Geriatrics Society*, 61(2), 252-257. doi: 10.1111/jgs.12091
- Hakamies-Blomqvist, L. (1994). Compensation in older drivers as reflected in their fatal accidents. *Accident Analysis and Prevention*, 26(1), 107-112. doi: 10.1016/0001-4575(94)90073-6
- Hakamies-Blomqvist, L. (1998). Older drivers' accident risk: Conceptual and methodological issues. *Accident Analysis and Prevention*, 30(3), 293-297. doi: 10.1016/S0001-4575(97)00120-6
- Hakamies-Blomqvist, L. (2002). What do crash statistics tell us and what can we expect in the future? In *Transcript of proceedings: Mobility and safety of older people conference*,

August 2002, Melbourne (pp. 27-43). Melbourne, Victoria: Australian College of Road Safety.

Hakamies-Blomqvist, L., Johansson, K., & Lundberg, C. (1996). Medical screening of older drivers as a traffic safety measure - a comparative Finnish-Swedish evaluation study.

Journal of the American Geriatrics Society, 44(6), 650-653. Retrieved from
<http://www.ncbi.nlm.nih.gov/pubmed/8642154>

Hakamies-Blomqvist, L., Raitanen, T., & O'Neill, D. (2002). Driver ageing does not cause higher accident rates per km. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(4), 271-274. doi: 10.1016/S1369-8478(03)00005-6

Hakamies-Blomqvist, L. E. (1993). Fatal accidents of older drivers. *Accident Analysis and Prevention*, 25(1), 19-27. doi: 10.1016/0001-4575(93)90093-C

Hanrahan, R. B., Layde, P. M., Zhu, S., Guse, C. E., & Hargarten, S. W. (2009). The association of driver age with traffic injury severity in Wisconsin. *Traffic Injury Prevention*, 10(4), 361-367. doi: 10.1080/15389580902973635

Hanson, T. R., & Hildebrand, E. D. (2011a). Are age-based licensing restrictions a meaningful way to enhance rural older driver safety? The need for exposure considerations in policy development. *Traffic Injury Prevention*, 12(1), 24-30. doi: 10.1080/15389588.2010.524957

Hanson, T. R., & Hildebrand, E. D. (2011b). Are rural older drivers subject to low-mileage bias? *Accident Analysis and Prevention*, 43(5), 1872-1877. doi: 10.1016/j.aap.2011.04.028

Hanson, T. R., & Hildebrand, E. D. (2011c). Can rural older drivers meet their needs without a car? Stated adaptation responses from a GPS travel diary survey. *Transportation*, 38(6), 975-992. doi: 10.1007/s11116-011-9323-3

Hansotia, P., & Broste, S. K. (1991). The effect of epilepsy or diabetes mellitus on the risk of automobile accidents. *The New England Journal of Medicine*, 324, 22-26. doi: 10.1056/NEJM199101033240105

Hansotia, P., & Broste, S. K. (1993). Epilepsy and traffic safety. *Epilepsia*, 34(5), 852-858. doi: 10.1111/j.1528-1157.1993.tb02102.x

Harris, A. (2002). Transitional issues. In *Transcript of proceedings: Mobility and safety of older people conference, August 2002, Melbourne* (pp. 67-81). Melbourne, Victoria: Australian College of Road Safety.

Haymes, S. A., LeBlanc, R. P., Nicolela, M. T., Chiasson, L. A., & Chauhan, B. C. (2007). Risk of falls and motor vehicle collisions in glaucoma. *Investigative Ophthalmology and Visual Science*, 48(3), 1149-1155. doi: 10.1167/iovs.06-0886

Haymes, S. A., LeBlanc, R. P., Nicolela, M. T., Chiasson, L. A., & Chauhan, B. C. (2008). Glaucoma and on-road driving performance. *Investigative Ophthalmology and Visual Science*, 49(7), 3035-3041. doi: 10.1167/iovs.07-1609

Hebert, C., Delaney, J. A. C., Hemmelgarn, B., Lévesque, L. E., & Suissa, S. (2007). Benzodiazepines and elderly drivers: A comparison of pharmacoepidemiological study designs. *Pharmacoepidemiology and Drug Safety*, 16(8), 845-849. doi: 10.1002/pds.1432

Heikkilä, V. M., Turkka, J., Korpelainen, J., Kallanranta, T., & Summala, H. (1998). Decreased driving ability in people with Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, 64(3), 325-330. doi: 10.1136/jnnp.64.3.325

Hemmelgarn, B., Lévesque, L. E., & Suissa, S. (2006). Anti-diabetic drug use and the risk of motor vehicle crash in the elderly. *The Canadian Journal of Clinical Pharmacology*, 13(1), e112-e120. Retrieved from <http://www.jptcp.com/pubmed.php?articleId=85>

- Hemmelmarn, B., Suissa, S., Huang, A., Boivin, J. F., & Pinard, G. (1997). Benzodiazepine use and the risk of motor vehicle crash in the elderly. *Journal of the American Medical Association*, 278(1), 27-31. doi: 10.1001/jama.1997.03550010041037
- Herriotts, P. (2005). Identification of vehicle design requirements for older drivers. *Applied Ergonomics*, 36(3), 255-262. doi: 10.1016/j.apergo.2005.01.002
- Hildebrand, E., Gordon, M., & Hanson, T. (2004). *Understanding the travel behaviour of the rural elderly*. Paper presented at the 39th Annual Conference of the Canadian Transportation Research Forum: Revolutions in Transportation, ISSN, Calgary, Alberta, Canada. Retrieved from http://www.unb.ca/research/transportation-group/_resources/pdf/research-papers/understanding-the-travel-behaviour-of-the-rural-elderly.pdf
- Hjorthol, R. J., Levin, L., & Siren, A. (2010). Mobility in different generations of older persons: The development of daily travel in different cohorts in Denmark, Norway and Sweden. *Journal of Transport Geography*, 18(5), 624-633. doi: 10.1016/j.jtrangeo.2010.03.011
- Holland, C. A., & Rabbitt, P. M. A. (1992). People's awareness of their age-related sensory and cognitive deficits and the implications for road safety. *Applied Cognitive Psychology*, 6(3), 217-231. doi: 10.1002/acp.2350060304
- Holland, C. A., & Rabbitt, P. M. A. (1994). The problems of being an older driver: Comparing the perceptions of an expert group and older drivers. *Applied Ergonomics*, 25(1), 17-27. doi: 10.1016/0003-6870(94)90026-4
- Hough, J. A., Cao, X., & Handy, S. L. (2008). Exploring travel behavior of elderly women in rural and small urban North Dakota. *Transportation Research Record: Journal of the Transportation Research Board*, 2082, 125-131. doi: 10.3141/2082-15
- Hu, P. S., Jones, D. W., Reuscher, T., Schmoyer Jr, R. S., & Truett, L. F. (2000). *Projecting fatalities in crashes involving older drivers, 2000-2025* (Report No. ORNL-6963).

- Oak Ridge, Tennessee: Oak Ridge National Laboratory. Retrieved from http://www-cta.ornl.gov/cta/Publications/Older_Drivers/index.html
- Huebner, K. D., Porter, M. M., & Marshall, S. C. (2006). Validation of an electronic device for measuring driving exposure. *Traffic Injury Prevention*, 7(1), 76-80. doi: 10.1080/15389580500413067
- Huisingsh, C., McGwin Jr, G., Wood, J. M., & Owsley, C. (2014). The driving visual field and a history of motor vehicle collision involvement in older drivers: A population-based examination. *Investigative Ophthalmology & Visual Science*. Advance online publication. doi: 10.1167/iovs.14-15194
- Hunt, L., Morris, J. C., Edwards, D., & Wilson, B. S. (1993). Driving performance in persons with mild senile dementia of the Alzheimer type. *Journal of the American Geriatrics Society*, 41(7), 747-752. Retrieved from <http://psycnet.apa.org/psycinfo/1994-02477-001>
- Ivers, R. Q., Boptom, P. M., & Cumming, R. G. (1999). Sensory impairment and driving: The Blue Mountains Eye Study. *American Journal of Public Health*, 89(1), 85-87. doi: 10.2105/AJPH.89.1.85
- Jaarsma, R., Louwerse, R., Dijkstra, A., de Vries, J., & Spaas, J. P. (2011). Making minor rural road networks safer: The effects of 60 km/h-zones. *Accident Analysis and Prevention*, 43(4), 1508-1515. doi: 10.1016/j.aap.2011.03.001
- Janke, M. K. (1991). Accidents, mileage, and the exaggeration of risk. *Accident Analysis and Prevention*, 23(2-3), 183-188. doi: 10.1016/0001-4575(91)90048-A
- Janke, M. K. (1994). *Age related disabilities that may impair driving and their assessment* (Report No. CAL-DMV-RSS-94-156). Sacramento, California: California State Department of Motor Vehicles. Retrieved from https://www.dmv.ca.gov/about/profile/rd/r_d_report/Section%206/156-Age-Related%20Disability.pdf

Janke, M. K. (2001). Assessing older drivers: Two studies. *Journal of Safety Research*, 32(1), 43-74. doi: 10.1016/S0022-4375(00)00048-7

Johansson, K., Bronge, L., Lundberg, C., Persson, A., Seideman, M., & Viitanen, M. (1996). Can a physician recognize an older driver with increased crash risk potential? *Journal of the American Geriatrics Society*, 44(10), 1198-1204. Retrieved from <http://europepmc.org/abstract/MED/8855998>

Johansson, K., Byding, G., Dahl, M., Holmgren, P., & Viitanen, M. (1997). Traffic dangerous drugs are often found in fatally injured older male drivers. *Journal of the American Geriatrics Society*, 45(8), 1029-1031. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9256861>

Johansson, P. (1996). Speed limitation and motorway casualties: A time series count data regression approach. *Accident Analysis and Prevention*, 28(1), 73-87. doi: 10.1016/0001-4575(95)00043-7

Johnson, J. E. (1995). Rural elders and the decision to stop driving. *Journal of Community Health Nursing*, 12(3), 131-138. doi: 10.1207/s15327655jchn1203_1

Johnson, J. E. (2002). Why rural elders drive against advice. *Journal of Community Health Nursing*, 19(4), 237-244. doi: 10.1207/S15327655JCHN1904_04

Johnstone, O. (2004). *Automatic crash notification devices* (Report No. AP-R253/04). Sydney: Austroads. Retrieved from <https://www.onlinepublications.austroads.com.au/items/AP-R253-04>

Kahane, C. J. (2013). *Injury vulnerability and effectiveness of occupant protection technologies for older occupants and women* (Report No. DOT HS 811 766).

Washington DC: National Highway Traffic Safety Administration. Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811766.PDF>

Kaufman, D. W., Kelly, J. P., Rosenberg, L., Anderson, T. E., & Mitchell, A. A. (2002). Recent patterns of medication use in the ambulatory adult population of the United

- States: The Sloane Survey. *Journal of the American Medical Association*, 287(3), 337-344. doi: 10.1001/jama.287.3.337.
- Kelleher, K. J., Pope, S. K., Kirby, R. S., & Rickert, V. I. (1996). Alcohol availability and motor vehicle fatalities. *Journal of Adolescent Health*, 19(5), 325-330. doi: 10.1016/S1054-139X(96)00089-4
- Klavora, P., & Heslegrave, R. L. (2002). Senior drivers: An overview of problems and intervention strategies. *Journal of Aging and Physical Activity*, 10(3), 322-335. Retrieved from <http://journals.humankinetics.com/japa-back-issues/JAPAVolume10Issue3July/SeniorDriversAnOverviewofProblemsandInterventionStrategies>
- Klein, R. (1991). Age-related eye disease, visual impairment, and driving in the elderly. *Human Factors*, 33(5), 521-525. doi: 10.1177/001872089103300504
- Kloeden, C. N. (2008). *The crash and offence experience of newly licensed young drivers* (Report No. AP-R331/08). Sydney: Austroads. Retrieved from <https://www.onlinepublications.austroads.com.au/items/AP-R331-08>
- Kloeden, C. N., Ponte, G., & McLean, A. J. (2001). *Travelling Speed and the risk of crash involvement on rural roads* (Report No. CR204). Canberra: Australian Transport Safety Bureau. Retrieved from http://www.infrastructure.gov.au/roads/safety/publications/2001/Rural_Speed_1.aspx
- Kmet, L., & Macarthur, C. (2006). Urban-rural differences in motor vehicle crash fatality and hospitalization rates among children and youth. *Accident Analysis and Prevention*, 38(1), 122-127. doi: 10.1016/j.aap.2005.07.007
- Koepsell, T. D., Wolf, M. E., McCloskey, L., Buchner, D. M., Louie, D., Wagner, E. H., & Thompson, R. S. (1994). Medical conditions and motor vehicle collision injuries in older adults. *Journal of the American Geriatrics Society*, 42(7), 695-700. Retrieved from <http://europepmc.org/abstract/MED/8014341>

Koppel, S., Clark, B., Hoareau, E., Charlton, J. L., & Newstead, S. V. (2013). How important

is vehicle safety for older consumers in the vehicle purchase process? *Traffic Injury*

Prevention, 14(6), 592-601. doi: 10.1080/15389588.2012.740642

Kostyniuk, L. P., & Molnar, L. J. (2008). Self-regulatory driving practices among older

adults: Health, age and sex effects. *Accident Analysis and Prevention*, 40(4), 1576-

1580. doi: 10.1016/j.aap.2008.04.005

Kostyniuk, L. P., & Shope, J. T. (2003). Driving and alternatives: Older drivers in Michigan.

Journal of Safety Research, 34(4), 407-414. doi: 10.1016/j.jsr.2003.09.001

Kowalski, K., Jeznach, A., & Tuokko, H. A. (2014). Stages of behavior change within the

Transtheoretical Model (TM). *Journal of Safety Research*, 50, 17-25. doi:

10.1016/j.jsr.2014.01.002

Kulikov, E. (2011). The social and policy predictors of driving mobility among older adults.

Journal of Aging and Social Policy, 23(1), 1-18. doi: 10.1080/08959420.2011.531991

Lange, J. E., & McKnight, A. J. (1996). Age-based road test policy evaluation.

Transportation Research Board: Journal of the Transportation Research Board, 1550,

81-87. doi: 10.3141/1550-11

Langford, J. (2008). Usefulness of off-road screening tests to Licensing Authorities when

assessing older driver fitness to drive. *Traffic Injury Prevention*, 9(4), 328-335. doi:

10.1080/15389580801895178

Langford, J. (2009). Older driver crashes. In M. Odell (Ed.), *Older road users* (pp. 1-23).

Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.

Langford, J., Bohensky, M., Koppel, S., & Newstead, S. (2008). Do age-based mandatory

assessments reduce older drivers' risk to other road users? *Accident Analysis and*

Prevention, 40(6), 1913-1918. doi: 10.1016/j.aap.2008.08.010

Langford, J., Braitman, K., Charlton, J., Eberhard, J., O'Neill, D., Staplin, L., & Stutts, J.

(2008). TRB Workshop 2007: Licensing authorities' options for managing older driver

- safety—practical advice from the researchers. *Traffic Injury Prevention*, 9(4), 278-281. doi: 10.1080/15389580801895210
- Langford, J., Charlton, J., Bohensky, M., Irving, J., Martin, L., & Fildes, B. (2009). *Older driver model assessment program: Stage 4 — validation of screening tests to assess at-risk older drivers* (Report No. AP-R336/09). Sydney: Austroads.
- Langford, J., Charlton, J. L., Koppel, S., Myers, A., Tuokko, H., Marshall, S., Man-Son-Hing, M., Darzins, P., Di Stefano, M., & Macdonald, W. (2013). Findings from the Candrive/Ozcandrive study: Low mileage older drivers, crash risk and reduced fitness to drive. *Accident Analysis and Prevention*, 61, 304-310. doi: 10.1016/j.aap.2013.02.006
- Langford, J., Fitzharris, M., Koppel, S., & Newstead, S. (2004). Effectiveness of mandatory license testing for older drivers in reducing crash risk among urban older Australian drivers. *Traffic Injury Prevention*, 5(4), 326-335. doi: 10.1080/15389580490509464
- Langford, J., Fitzharris, M., Newstead, S., & Koppel, S. (2004). Some consequences of different older driver licensing procedures in Australia. *Accident Analysis and Prevention*, 36(6), 993-1001. doi: 10.1016/j.aap.2003.11.003
- Langford, J., & Koppel, S. (2006a). The case for and against mandatory age-based assessment of older drivers. *Transportation Research Part F*, 9(5), 353-362. doi: 10.1016/j.trf.2006.06.009
- Langford, J., & Koppel, S. (2006b). Epidemiology of older driver crashes - Identifying older driver risk factors and exposure patterns. *Transportation Research Part F: Traffic Psychology and Behaviour*, 9(5), 309-321. doi: 10.1016/j.trf.2006.03.005
- Langford, J., Koppel, S., Andrea, D., & Fildes, B. (2006). Determining older driver crash responsibility from police and insurance data. *Traffic Injury Prevention*, 7(4), 343-351. doi: 10.1080/15389580600840706

- Langford, J., Methorst, R., & Hakamies-Blomqvist, L. (2006). Older drivers do not have a high crash risk - A replication of low mileage bias. *Accident Analysis and Prevention*, 38(3), 574-578. doi: 10.1016/j.aap.2005.12.002
- Langlois, J. A., Keyl, P. M., Guralnik, J. M., Foley, D. J., Marottoli, R. A., & Wallace, R. B. (1997). Characteristics of older pedestrians who have difficulty crossing the street. *American Journal of Public Health*, 87(3), 393-397. doi: 10.2105/AJPH.87.3.393
- Larsen, L., & Kines, P. (2002). Multidisciplinary in-depth investigations of head-on and left-turn road collisions. *Accident Analysis and Prevention*, 34(3), 367-380. doi: 10.1016/S0001-4575(01)00034-3
- Lee, H. C., Cameron, D., & Lee, A. H. (2003). Assessing the driving performance of older adult drivers: On-road versus simulated driving. *Accident Analysis and Prevention*, 35(5), 797-803. doi: 10.1016/S0001-4575(02)00083-0
- Leicht, M. J., Dula, D. J., Brotman, S., Anderson, T. E., Gessner, H. W., Parrish, G. A., & Rose, W. D. (1986). Rural interhospital helicopter transport of motor vehicle trauma victims: Causes for delays and recommendations. *Annals of Emergency Medicine*, 15(4), 450-453. doi: 10.1016/S0196-0644(86)80186-X
- Lesikar, S. E., Gallo, J. J., Rebok, G. W., & Keyl, P. M. (2002). Prospective study of brief neuropsychological measures to assess crash risk in older primary care patients. *The Journal of the American Board of Family Practice*, 15(1), 11-19. Retrieved from <http://www.jabfm.com/content/15/1/11.full.pdf+html>
- Leveille, S. G., Buchner, D. M., Koepsell, T. D., McCloskey, L. W., Wolf, M. E., & Wagner, E. H. (1994). Psychoactive medications and injurious motor vehicle collisions involving older drivers. *Epidemiology*, 5(6), 591-598. Retrieved from http://journals.lww.com/epidem/Abstract/1994/11000/Psychoactive_Medications_and_Injurious_Motor.6.aspx

Li, G., Braver, E. R., & Chen, L. H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers.

Accident Analysis and Prevention, 35(2), 227-235. doi: 10.1016/S0001-4575(01)00107-5

Li, G., Shahpar, C., Grabowski, J. G., & Baker, S. P. (2001). Secular trends of motor vehicle mortality in the United States, 1910-1994. *Accident Analysis and Prevention*, 33(3), 423-432. doi: 10.1016/S0001-4575(00)00056-7

Liddle, J., McKenna, K., & Bartlett, H. (2007). Improving outcomes for older retired drivers: The UQDRIVE program. *Australian Occupational Therapy Journal*, 54(4), 303-306. doi: 10.1111/j.1440-1630.2006.00614.x

Lindsay, T., & Ryan, T. (2011). *Medical conditions as a contributing factor in crash causation* (Report No. AP-R389-11). Sydney: Austroads. Retrieved from <https://www.onlinepublications.austroads.com.au/items/AP-R389-11>

Lister, R. (1999). Loss of ability to drive following a stroke: The early experiences of three elderly people on discharge from hospital. *The British Journal of Occupational Therapy*, 62(11), 514-520. Retrieved from <http://adelaideus.library.ingentaconnect.com/content/cot/bjot/1999/00000062/00000011/art00006>

Long, A. D., Kloeden, C. N., Hutchinson, T. P., & McLean, A. J. (2006). *Reduction of speed limit from 110km/h to 100km/h on certain roads in South Australia: a preliminary evaluation* (Report No. CASR024). Adelaide: Centre for Automotive Safety Research. Retrieved from <http://casr.adelaide.edu.au/casrpublish/show.php?id=566>

Lundberg, C., Hakamies-Blomqvist, L., Almkvist, O., & Johansson, K. (1998). Impairments of some cognitive functions are common in crash-involved older drivers. *Accident Analysis and Prevention*, 30(3), 371-377. doi: 10.1016/S0001-4575(97)00111-5

Lundqvist, A., Gerdle, B., & Rönnberg, J. (2000). Neuropsychological aspects of driving after

a stroke - in the simulator and on the road. *Applied Cognitive Psychology*, 14(2), 135-

150. doi: 10.1002/(SICI)1099-0720(200003/04)14:2<135::AID-ACP628>3.0.CO;2-S

Lyman, J. M., McGwin Jr, G., & Sims, R. V. (2001). Factors related to driving difficulty and

habits in older drivers. *Accident Analysis and Prevention*, 33(3), 413-421. doi:

10.1016/S0001-4575(00)00055-5

Lyman, S., Ferguson, S. A., Braver, E. R., & Williams, A. F. (2002). Older drivers

involvements in police reported crashes and fatal crashes: Trends and projections.

Injury Prevention, 8(2), 116-120. doi: 10.1136/ip.8.2.116

Madeley, P., Hulley, J. L., Wildgust, H., & Mindham, R. H. (1990). Parkinson's disease and

driving ability. *Journal of Neurology, Neurosurgery and Psychiatry*, 53(7), 580-582.

doi: 10.1136/jnnp.53.7.580

Madhusoodanan, S., & Bogunovic, O. J. (2004). Safety of benzodiazepines in the geriatric

population. *Expert Opinion on Drug Safety*, 3(5), 485-493. doi:

10.1517/14740338.3.5.485

Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor

vehicle crash mortality: The role of crash severity and medical resources. *Accident*

Analysis and Prevention, 24(6), 631-642. doi: 10.1016/0001-4575(92)90015-B

Mangione, C. M., Gutierrez, P. R., Lowe, G., Orav, E. J., & Seddon, J. M. (1999). Influence

of age-related maculopathy on visual functioning and health-related quality of life.

American Journal of Ophthalmology, 128(1), 45-53. doi: 10.1016/S0002-

9394(99)00169-5

Marottoli, R. A. (2002). Health issues for older road users. In *Transcript of proceedings:*

Mobility and safety of older people conference, August 2002, Melbourne (pp. 1-26).

Melbourne, Victoria: Australian College of Road Safety.

Marottoli, R. A., Cooney, L. M., Jr., & Tinetti, M. E. (1997). Self-report versus state records

for identifying crashes among older drivers. *Journal of Gerontology: Medical*

sciences, 52A(3), M184-M187. doi: 10.1093/gerona/52A.3.M184

Marottoli, R. A., Cooney, L. M., Jr., Wagner, D. R., Douchette, J., & Tinetti, M. E. (1994).

Predictors of automobile crashes and moving violations among elderly drivers. *Annals*

of Internal Medicine, 121(11), 842-846. doi: 10.7326/0003-4819-121-11-199412010-

00003

Marottoli, R. A., & Coughlin, J. F. (2011). Walking the tightrope: Developing a systems

approach to balance safety and mobility for an aging society. *Journal of Aging and*

Social Policy, 23(4), 372-383. doi: 10.1080/08959420.2011.605655

Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., &

Berkman, L. F. (2000). Consequences of driving cessation: Decreased out-of-home

activity levels. *Journal of Gerontology: Social Sciences, 55B(6)*, S334-S340. doi:

10.1093/geronb/55.6.S334

Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr.,

Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive

symptoms: Prospective evidence from the New Haven Established Populations for

Epidemiological Studies of the Elderly. *Journal of the American Geriatrics Society,*

45(2), 202-206. Retrieved from <http://psycnet.apa.org/psycinfo/1997-07396-004>

Marottoli, R. A., Richardson, E. D., Stowe, M. H., Miller, E. G., Brass, L. M., Cooney, L. M.,

Jr., & Tinetti, M. E. (1998). Development of a test battery to identify older drivers at

risk for self-reported adverse driving events. *Journal of the American Geriatrics*

Society, 46(5), 562-568. Retrieved from

<http://www.ncbi.nlm.nih.gov/pubmed/9588368>

Marshall, S. C., Wilson, K. G., Molnar, F. J., Man-Son-Hing, M., Stiell, I., & Porter, M. M.

(2007). Measurement of driving patterns of older adults using data logging devices

- with and without global positioning system capability. *Traffic Injury Prevention*, 8(3), 260-266. doi: 10.1080/15389580701281792
- Martin, A. J., Hand, E. B., Trace, F., & O'Neill, D. (2010). Pedestrian fatalities and injuries involving Irish older people. *Gerontology*, 56(3), 266-271. doi: 10.1159/000258052
- Mathias, J. L., & Lucas, L. K. (2009). Cognitive predictors of unsafe driving in older drivers: A meta-analysis. *International Psychogeriatrics*, 21(4), 637-653. doi: 10.1017/S1041610209009119
- Mattson, J. (2013). *Rural Transit Fact Book 2013*. Tampa, Florida: National Centre for Transit Research. Retrieved from http://www.surtc.org/transitfactbook/downloads/2013_rural_transit_fact_book.pdf
- Mattson, J. W. (2011). Aging and mobility in rural and small urban areas: A survey of North Dakota. *Journal of Applied Gerontology*, 30(6), 700-718. doi: 10.1177/0733464811378107
- Maycock, G. (1997). *The safety of older car-drivers in the European Union*. Basingstoke: AA Foundation for Road Safety Research. Retrieved from <http://trid.trb.org/view.aspx?id=471675>
- Mayhew, D. R., Simpson, H. M., & Ferguson, S. A. (2006). Collisions involving senior drivers: High-risk conditions and locations. *Traffic Injury Prevention*, 7(2), 117-124. doi: 10.1080/15389580600636724
- McGwin Jr, G., & Brown, D. B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident Analysis and Prevention*, 31(3), 181-198. doi: 10.1016/S0001-4575(98)00061-X
- McGwin Jr, G., Owsley, C., & Ball, K. (1998). Identifying crash involvement among older drivers: Agreement between self-report and state records. *Accident Analysis and Prevention*, 30(6), 781-791. doi: 10.1016/S0001-4575(98)00031-1

- McGwin Jr, G., Sims, R. V., Pulley, L., & Roseman, J. M. (2000). Relations among chronic medical conditions, medications, and automobile crashes in the elderly: A population-based case-control study. *American Journal of Epidemiology*, 152(5), 424-431. doi: 10.1093/aje/152.5.424
- McGwin Jr, G., Xie, A., Mays, A., Joiner, W., DeCarlo, D. K., Hall, T. A., & Owsley, C. (2005). Visual field defects and the risk of motor vehicle collisions among patients with glaucoma. *Investigative Ophthalmology and Visual Science*, 46(12), 4437-4441. doi: 10.1167/iovs.05-0750
- McKenna, P., Jefferies, L., Dobson, A., & Frude, N. (2004). The use of a cognitive battery to predict who will fail an on-road driving test. *British Journal of Clinical Psychology*, 43(3), 325-336. doi: 10.1348/0144665031752952
- Meng, A., & Siren, A. (2012). Cognitive problems, self-rated changes in driving skills, driving-related discomfort and self-regulation of driving in old drivers. *Accident Analysis and Prevention*, 49, 322-329. doi: 10.1016/j.aap.2012.01.023
- Meuleners, L. B., Harding, A., Lee, A. H., & Legge, M. (2006). Fragility and crash overrepresentation among older drivers in Western Australia. *Accident Analysis and Prevention*, 38(5), 1006-1010. doi: 10.1016/j.aap.2006.04.005
- Mezuk, B., & Rebok, G. W. (2008). Social integration and social support among older adults following driving cessation. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 63B(5), S298-S303. doi: 10.1093/geronb/63.5.S298
- Mitchell, R. J., & Chong, S. (2010). Comparison of injury related hospitalised morbidity and mortality in urban and rural areas in Australia. *Rural and Remote Health*, 10(1), 1326-1333. Retrieved from <http://www.rrh.org.au/articles/subviewnew.asp?ArticleID=1326>
- Molnar, F. J., Patel, A., Marshall, S. C., Man-Son-Hing, M., & Wilson, K. G. (2006). Clinical utility of office-based cognitive predictors of fitness to drive in persons with dementia:

A systematic review. *Journal of the American Geriatrics Society*, 54(12), 1809-1824.

doi: 10.1111/j.1532-5415.2006.00967.x

Molnar, L. J., Charlton, J. L., Eby, D. W., Bogard, S. E., Langford, J., Koppel, S., . . . Man-Son-Hing, M. (2013). Self-regulation of driving by older adults: Comparison of self-report and objective driving data. *Transportation Research Part F: Traffic Psychology and Behaviour*, 20, 29-38. doi: 10.1016/j.trf.2013.05.001

Molnar, L. J., & Eby, D. W. (2008). The relationship between self-regulation and driving-related abilities in older drivers: an exploratory study. *Traffic Injury Prevention*, 9(4), 314-319. doi: 10.1080/15389580801895319

Molnar, L. J., Eby, D. W., Charlton, J. L., Langford, J., Koppel, S., Marshall, S., & Man-Son-Hing, M. (2013). Driving avoidance by older adults: Is it always self-regulation? *Accident Analysis and Prevention*, 57, 96-104. doi: 10.1016/j.aap.2013.04.010

Molnar, L. J., Eby, D. W., Langford, J., Charlton, J. L., St. Louis, R. M., & Roberts, J. S. (2013). Tactical, strategic, and life-goal self-regulation of driving by older adults: Development and testing of a questionnaire. *Journal of Safety Research*, 46, 107-117. doi: 10.1016/j.jsr.2013.05.001

Monárez-Espino, J., Laflamme, L., Elling, B., & Möller, J. (2013). Number of medications and road traffic crashes in senior Swedish drivers: A population-based matched case-control study. *Injury Prevention, Advanced online publication*. doi: 10.1136/injuryprev-2013-040762

Muelleman, R. L., & Mueller, K. (1996). Fatal motor vehicle crashes: Variations of crash characteristics within rural regions of different population densities. *Journal of Trauma-Injury Infection and Critical Care*, 41(2), 315-320. Retrieved from http://journals.lww.com/jtrauma/Abstract/1996/08000/Fatal_Motor_Vehicle_Crashes__Variations_of_Crash.20.aspx

Muelleman, R. L., Wadman, M. C., Tran, T. P., Ullrich, F., & Anderson, J. R. (2007). Rural

motor vehicle crash risk of death is higher after controlling for injury severity. *Journal*

of Trauma-Injury Infection and Critical Care, 62(1), 221-226. doi:

10.1097/01.ta.0000231696.65548.06

Muelleman, R. L., Walker, R. A., & Edney, J. A. (1993). Motor vehicle deaths: A rural

epidemic. *Journal of Trauma-Injury Infection and Critical Care*, 35(5), 717-719.

Retrieved from

http://journals.lww.com/jtrauma/Abstract/1993/11000/Motor_Vehicle_Deaths__A_Rural_Epidemic.11.aspx

Mullen, N., & Bédard, M. (2009). The end of driving. In M. Odell (Ed.), *Older road users*

(pp. 281-292). Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.

Mullen, N. W., Dubois, S., & Bédard, M. (2013). Fatality trends and projections for drivers

and passengers: Differences between observed and expected fatality rates with a focus

on older adults. *Safety Science*, 59, 106-115. doi: 10.1016/j.ssci.2013.05.005

NCD. (2005). *The current state of transportation for people with disabilities in the United*

States. Washington, DC: National Council on Disability. Retrieved from

<http://www.ncd.gov/publications/2005/06132005>

Newgard, C. D. (2008). Defining the "older" crash victim: The relationship between age and

serious injury in motor vehicle crashes. *Accident Analysis and Prevention*, 40(4),

1498-1505. doi: 10.1016/j.aap.2008.03.010

Newstead, S., Watson, L., & Cameron, M. (2008). *Vehicle safety ratings estimated from*

police reported crash data: 2008 update (Report No. 280). Melbourne: Monash

University Accident Research Centre. Retrieved from

<http://www.monash.edu.au/miri/research/reports/muarc280.pdf>

- NHTSA. (2013a). *Traffic safety facts 2011: Rural/urban comparison* (Report No. DOT HS 811 821). Washington, DC: National Highway Traffic Safety Administration.
- Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811821.pdf>
- NHTSA. (2013b). *Traffic safety facts 2011: Speeding* (Report No. DOT HS 811 751). Washington, DC: National Highway Traffic Safety Administration. Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811751.pdf>
- NHTSA. (2013c). *Traffic safety facts research note: How vehicle age and model year relate to driver injury severity in fatal crashes* (Report No. DOT HS 811 825). Washington, DC: National Highway Traffic Safety Administration. Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811825.pdf>
- Niewoehner, P. M., Henderson, R. R., Dalchow, J., Beardsley, T. L., Stern, R. A., & Carr, D. B. (2012). Predicting road test performance in adults with cognitive or visual impairment referred to a veterans affairs medical center driving clinic. *Journal of the American Geriatrics Society*, 60(11), 2070-2074. doi: 10.1111/j.1532-5415.2012.04201.x
- Nordbakke, S. (2013). Capabilities for mobility among urban older women: Barriers, strategies and options. *Journal of Transport Geography*, 26, 166-174. doi: 10.1016/j.jtrangeo.2012.10.003
- Nutley, S. (2003). Indicators of transport and accessibility problems in rural Australia. *Journal of Transport Geography*, 11(1), 55-71. doi: 10.1016/S0966-6923(02)00052-2
- O'Neill, D., Neubauer, K., Boyle, M., Gerrard, J., Surmon, D., & Wilcock, G. K. (1992). Dementia and driving. *Journal of the Royal Society of Medicine*, 85(4), 199-202. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1294722/>
- Odell, M. (2009). Introduction. In M. Odell (Ed.), *Older road users* (pp. ix-xvi). Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.

OECD. (2001). *Ageing and Transport: Mobility and Safety Issues*. Paris, France: Organisation for Economic Co-operation and Development.

Okonkwo, O. C., Crowe, M., Wadley, V. G., & Ball, K. (2008). Visual attention and self-regulation of driving among older adults. *International Psychogeriatrics*, 20(1), 162-173. doi: 10.1017/S104161020700539X

Ossiander, E. M., & Cummings, P. (2002). Freeway speed limits and traffic fatalities in Washington State. *Accident Analysis and Prevention*, 34(1), 13-18. doi: 10.1016/S0001-4575(00)00098-1

Ott, B. R., Heindel, W. C., Papandonatos, G. D., Festa, E. K., Davis, J. D., Daiello, L. A., & Morris, J. C. (2008). A longitudinal study of drivers with Alzheimer disease. *Neurology*, 70(14), 1171-1178. doi: 10.1212/01.wnl.0000294469.27156.30

Owsley, C., Ball, K., McGwin Jr, G., Sloane, M. E., Roenker, D. L., White, M. F., & Overley, E. T. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *Journal of the American Medical Association*, 279(14), 1083-1088. doi: 10.1001/jama.279.14.1083

Owsley, C., McGwin Jr, G., Phillips, J. M., McNeal, S. F., & Stalvey, B. T. (2004). Impact of an educational program on the safety of high-risk, visually impaired, older drivers. *American Journal of Preventive Medicine*, 26(3), 222-229. doi: 10.1016/j.amepre.2003.12.005

Owsley, C., McGwin Jr, G., Sloane, M. E., Wells, J., Stalvey, B., & Gauthreaux, S. (2002). Impact of cataract surgery on motor vehicle crash involvement by older adults. *Journal of the American Medical Association*, 288(7), 841-849. doi: 10.1001/jama.288.7.841

Owsley, C., Stalvey, B., Wells, J., & Sloane, M. E. (1999). Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology: Medical Sciences*, 54A(4), M203-M211. doi: 10.1093/gerona/54.4.M203

- Owsley, C., Stalvey, B. T., & Phillips, J. M. (2003). The efficacy of an educational intervention in promoting self-regulation among high-risk older drivers. *Accident Analysis and Prevention*, 35(3), 393-400. doi: 10.1016/S0001-4575(02)00016-7
- Oxley, J. (2009). Walking for older road users: A safe alternative to the car? In M. Odell (Ed.), *Older road users* (pp. 197-224). Tucson, Arizona: Lawyers and Judges Publishing Company, Inc.
- Oxley, J., Charlton, J., & Fildes, B. (2003). *Self-regulation of older drivers: A review* (Report No. AP-R221/03). Sydney: Austroads. Retrieved from <http://trid.trb.org/view.aspx?id=678620>
- Oxley, J., Ihsen, E., Fildes, B. N., Charlton, J. L., & Day, R. H. (2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. *Accident Analysis and Prevention*, 37(5), 962-971. doi: 10.1016/j.aap.2005.04.017
- Oxley, J., & Whelan, M. (2008). It cannot be all about safety: The benefits of prolonged mobility. *Traffic Injury Prevention*, 9(4), 367-378. doi: 10.1080/15389580801895285
- Peel, N., Westmoreland, J., & Steinberg, M. (2002). Transport safety for older people: A study of their experiences, perceptions and management needs. *Injury Control and Safety Promotion*, 9(1), 19-24. doi: 10.1076/icsp.9.1.19.3327
- Persson, A. (1993). The elderly driver: Deciding when to stop driving. *The Gerontologist*, 33(1), 88-91. doi: 10.1093/geront/33.1.88
- Ponte, G., Anderson, R. W. G., & Ryan, G. A. (2013). *The characteristics of fatal crashes in South Australia involving a delay in notifying Emergency Medical Services*. Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Brisbane, Queensland. Retrieved from <http://acrs.org.au/files/arsrpe/Paper%20154%20-%20Ponte%20-%20Post%20Crash%20Response.pdf>

Poulter, D. R., & Wann, J. P. (2013). Errors in motion processing amongst older drivers may

increase accident risk. *Accident Analysis and Prevention*, 57, 150-156. doi:

10.1016/j.aap.2013.03.031

Preusser, D. F., Williams, A. F., Ferguson, S. A., Ulmer, R. G., & Weinstein, H. B. (1998).

Fatal crash risk for older drivers at intersections. *Accident Analysis and Prevention*,

30(2), 151-159. doi: 10.1016/S0001-4575(97)00090-0

Pucher, J., & Renne, J. L. (2005). Rural mobility and mode choice: Evidence from the 2001

National Household Travel Survey. *Transportation*, 32(2), 165-186. doi:

10.1007/s11116-004-5508-3

Ragland, D. R., Satariano, W. A., & MacLeod, K. E. (2004). Reasons given by older people

for limitation or avoidance of driving. *The Gerontologist*, 44(2), 237-244. doi:

10.1093/geront/44.2.237

Ragland, D. R., Satariano, W. A., & MacLeod, K. E. (2005). Driving cessation and increased

depressive symptoms. *The Journals of Gerontology, Series A: Biological Sciences and*

Medical Sciences, 60A(3), 399-403. doi: 10.1093/gerona/60.3.399

Raitanen, T., Tormakangas, T., Mollenkopf, H., & Marcellini, F. (2003). Why do older

drivers reduce driving? Findings from three European countries. *Transportation*

Research Part F: Traffic Psychology and Behaviour, 6(2), 81-95. doi: 10.1016/S1369-

8478(03)00007-X

Rakotonirainy, A., Steinhardt, D., Delhomme, P., Darvell, M., & Schramm, A. (2012). Older

drivers' crashes in Queensland, Australia. *Accident Analysis and Prevention*, 48, 423-

429. doi: 10.1016/j.aap.2012.02.016

Ray, W. A., Fought, R. L., & Decker, M. D. (1992). Psychoactive drugs and the risk of

injurious motor vehicle crashes in elderly drivers. *American Journal of Epidemiology*,

136(7), 873-883. doi: 10.1093/aje/136.7.873

Ray, W. A., Gurwitz, J., Decker, M. D., & Kennedy, D. L. (1992). Medications and the safety

of the older driver: Is there a basis for concern? *Human Factors*, 34(1), 33-47. doi:

10.1177/001872089203400105

Richards, D. C. (2010). *Relationship between speed and risk of fatal injury. Pedestrians and*

car occupants (Report No. RSWP 16). London: Department for Transport. Retrieved

from <https://www.gov.uk/government/policies/making-roads-safer>

Richardson, E. D., & Marottoli, R. A. (2003). Visual attention and driving behaviours among

community-living older persons. *The Journals of Gerontology, Series A: Biological*

Sciences and Medical Sciences, 58(9), M832-M836. doi: 10.1093/gerona/58.9.M832

Rimmo, P. A., & Hakamies-Blomqvist, L. (2002). Older drivers' aberrant driving behaviour,

impaired activity, and health as reasons for self-imposed driving limitations.

Transportation Research Part F: Traffic Psychology and Behaviour, 5(1), 47-62. doi:

10.1016/S1369-8478(02)00005-0

Rizzo, M., McGehee, D. V., Dawson, J. D., & Anderson, S. N. (2001). Simulated car crashes

at intersections in drivers with Alzheimer Disease. *Alzheimer Disease and Associated*

Disorders, 15(1), 10-20. Retrieved from

http://journals.lww.com/alzheimerjournal/Abstract/2001/01000/Simulated_Car_Crashes_at_Intersections_in_Drivers.2.aspx

Rock, S. M. (1998). Impact from changes in Illinois drivers license renewal requirements for

older drivers. *Accident Analysis and Prevention*, 30(1), 69-74. doi: 10.1016/S0001-

4575(97)00063-8

Romero-Ortuno, R., Cogan, L., Cunningham, C. U., & Kenny, R. A. (2010). Do older

pedestrians have enough time to cross roads in Dublin? A critique of the Traffic

Management Guidelines based on clinical research findings. *Age and Ageing*, 39(1),

80-86. doi: 10.1093/ageing/afp206

- Romoser, M. R. E., Pollatsek, A., Fisher, D. L., & Williams, C. C. (2013). Comparing the glance patterns of older versus younger experienced drivers: Scanning for hazards while approaching and entering the intersection. *Transportation Research Part F: Traffic Psychology and Behaviour*, 16, 104-116. doi: 10.1016/j.trf.2012.08.004
- Rose, A. J. (1977). Urban and rural settlements. In E. Loffler, A. J. Rose & D. Warner (Eds.), *Australia* (pp. 165-188). Richmond, Victoria: Hutchinson Australia.
- Rosenbloom, S. (2001). Driving cessation among older people: When does it happen and what impact does it have? *Transportation Research Record: Journal of the Transportation Research Board*, 1779, 93-99. doi: 10.3141/1779-13
- Rosenbloom, S. (2004). *The mobility needs of older Americans: Implications for transportation reauthorization*. Washington, DC: The Brookings Institution. Retrieved from <http://trid.trb.org/view.aspx?id=839899>
- Ross, L. A., Clay, O. J., Edwards, J. D., Ball, K. K., Wadley, V. G., Vance, D. E., . . . Joyce, J. J. (2009). Do older drivers at-risk for crashes modify their driving over time? *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 64B(2), 163-170. doi: 10.1093/geronb/gbn034
- Ross, L. A., Schmidt, E. L., & Ball, K. (2013). Interventions to maintain mobility: What works? *Accident Analysis and Prevention*, 61, 167-196. doi: 10.1016/j.aap.2012.09.027
- Rubin, G. S., Ng, E. S. W., Bandeen-Roche, K. J., Keyl, P. M., Freeman, E. E., West, S. K., & Team, S. P. (2007). A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: The SEE Study. *Investigative Ophthalmology and Visual Science*, 48(4), 1483-1491. doi: 10.1167/iovs.06-0474

Rudman, D. L., Friedland, J., Chipman, M., & Sciortino, P. (2006). Holding on and letting go:

The perspectives of pre-seniors and seniors on driving self-regulation in later life.

Canadian Journal on Aging, 25(1), 65-76. doi: 10.1353/cja.2006.0031

Ryan, G. A., Legge, M., & Rosman, D. (1998). Age related changes in driver's crash risk and crash type. *Accident Analysis and Prevention*, 30(3), 379-387. doi: 10.1016/S0001-4575(97)00098-5

Ryb, G. E., Dischinger, P. C., & Ho, S. (2009). Vehicle model year and crash outcomes: A CIREN study. *Traffic Injury Prevention*, 10(6), 560-566. doi: 10.1080/15389580903271401

Sagberg, F. (2006). Driver health and crash involvement: A case-control study. *Accident Analysis and Prevention*, 38(1), 28-34. doi: 10.1016/j.aap.2005.06.018

Satariano, W. A., MacLeod, K. E., Cohn, T. E., & Ragland, D. R. (2004). Problems with vision associated with limitations or avoidance of driving in older populations. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 59B(5), S281-S286. doi: 10.1093/geronb/59.5.S281

Sayeg, P. (2005). Introduction. In P. Sayeg & P. Charles (Eds.), *Transport innovation: A new era for Australia* (pp. 14-15). Lane Cove, New South Wales: CL Creations.

Schlag, B. (1993). Elderly drivers in Germany — Fitness and driving behavior. *Accident Analysis and Prevention*, 25(1), 47-55. doi: 10.1016/0001-4575(93)90095-E

Shaheen, S. A., & Niemeier, D. A. (2001). Integrating vehicle design and human factors: Minimizing elderly driving constraints. *Transportation Research Part C: Emerging Technologies*, 9(3), 155-174. doi: 10.1016/S0968-090X(99)00027-3

Shoval, N., Auslander, G., Cohen-Shalom, K., Isaacson, M., Landau, R., & Heinik, J. (2010). What can we learn about the mobility of the elderly in the GPS era? *Journal of Transport Geography*, 18(5), 603-612. doi: 10.1016/j.jtrangeo.2010.03.012

- Sihvola, N., Luoma, J., Schirokoff, A., Salo, J., & Karkola, K. (2009). In-depth evaluation of the effects of an automatic emergency call system on road fatalities. *European Transportation Research Review*, 1(3), 99-105. doi: 10.1007/s12544-009-0016-3
- Silverstein, N. M. (2008). When life exceeds safe driving expectancy: Implications for gerontology and geriatrics education. *Gerontology and Geriatrics Education*, 29(4), 305-309. doi: 10.1080/02701960802497795
- Sims, R. V., McGwin Jr, G., Allman, R. M., Ball, K., & Owsley, C. (2000). Exploratory study of incident vehicle crashes among older drivers. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences*, 55(1), M22-M27. doi: 10.1093/gerona/55.1.M22
- Siren, A., & Meng, A. (2012). Cognitive screening of older drivers does not produce safety benefits. *Accident Analysis and Prevention*, 45, 634-638. doi: 10.1016/j.aap.2011.09.032
- Siren, A., & Meng, A. (2013). Older drivers' self-assessed driving skills, driving-related stress and self-regulation in traffic. *Transportation Research Part F: Traffic Psychology and Behaviour*, 17, 88-97. doi: 10.1016/j.trf.2012.10.004
- Sivak, M., & Schoettle, B. (2012). Recent changes in the age composition of drivers in 15 countries. *Traffic Injury Prevention*, 13(2), 126-132. doi: 10.1080/15389588.2011.638016
- Smith, A., Marshall, S., Porter, M., Ha, L., Bédard, M., Gélinas, I., Man-Son-Hing, M., Mazer, B., Rapoport, M., Tuokko, H., & Vrkljan, B. (2013). Stability of physical assessment of older drivers over 1 year. *Accident Analysis and Prevention*, 61, 261-266. doi: 10.1016/j.aap.2013.02.007
- Snellgrove, C. A. (2005). *Older Drivers with Mild Cognitive Impairment or Early Dementia* (Doctoral thesis, University of Adelaide, Adelaide, Australia). Retrieved from <http://digital.library.adelaide.edu.au/theses/09PH/09phs6717.pdf>

- Sommer, S. M., Falkmer, T., Bekiaris, E., & Panou, M. (2004). Toward a client-centred approach to fitness-to-drive assessment of elderly drivers. *Scandinavian Journal of Occupational Therapy*, 11(2), 62-69. doi: 10.1080/11038120410020539
- Stalvey, B. T., & Owsley, C. (2000). Self perceptions and current practices of high risk older drivers: Implications for driver safety interventions. *Journal of Health Psychology*, 5(4), 441-456. doi: 10.1177/135910530000500404
- Stamatiadis, N., & Deacon, J. A. (1995). Trends in highway safety: Effects of an aging population on accident propensity. *Accident Analysis and Prevention*, 27(4), 443-459. doi: 10.1016/0001-4575(94)00086-2
- Stamatiadis, N., Taylor, W. C., & McKelvey, F. X. (1991). Older drivers and intersection traffic control devices. *Journal of Transportation Engineering*, 117(3), 311-319. doi: 10.1061/(ASCE)0733-947X(1991)117:3(311)
- Staplin, L., Gish, K. W., & Joyce, J. (2008). 'Low mileage bias' and related policy implications - A cautionary note. *Accident Analysis and Prevention*, 40, 1249-1252. doi: 10.1016/j.aap.2007.10.012
- Staplin, L., Gish, K. W., & Wagner, E. K. (2003). MaryPODS revisited: Updated crash analysis and implications for screening program implementation. *Journal of Safety Research*, 34(4), 389-397. doi: 10.1016/j.jsr.2003.09.002
- Stav, W. B. (2014). Updated systematic review on older adult community mobility and driver licensing policies. *American Journal of Occupational Therapy*, 68(6), 681-689. doi: 10.5014/ajot.2014.011510
- Stolwyk, R. J., Charlton, J. L., Triggs, T. J., Iansek, R., & Bradshaw, J. L. (2006). Neuropsychological function and driving ability in people with Parkinson's disease. *Journal of Clinical and Experimental Neuropsychology*, 28(6), 898-913. doi: 10.1080/13803390591000909

Stopher, P., FitzGerald, C., & Zhang, J. (2008). Search for a global positioning system device to measure person travel. *Transportation Research Part C*, 16(3), 350-369. doi: 10.1016/j.trc.2007.10.002

Stutts, J. C. (1998). Do older drivers with visual and cognitive impairments drive less? *Journal of the American Geriatrics Society*, 46(7), 854-861. Retrieved from <http://psycnet.apa.org/psycinfo/1998-04923-003>

Stutts, J. C., & Martell, C. (1992). Older driver population and crash involvement trends, 1974-1988. *Accident Analysis and Prevention*, 24(4), 317-327. doi: 10.1016/0001-4575(92)90044-J

Stutts, J. C., Wilkins, J. W., Reinfurt, D. W., Rodgman, E. A., & Van Heusen-Causey, S. (2001). *The premature reduction and cessation of driving by older men and women* (Report No. G.7). Chapel Hill, North Carolina: Highway Safety Research Centre.

Retrieved from <http://www.hsrc.unc.edu/pdf/2001/G7Report.pdf>

Sullivan, K. A., Smith, S. S., Horswill, M. S., & Lurie-Beck, J. K. (2011). Older adults' safety perceptions of driving situations: Towards a new driving self-regulation scale.

Accident Analysis and Prevention, 43(3), 1003-1009. doi: 10.1016/j.aap.2010.11.031

Szlyk, J. P., Mahler, C. L., Seiple, W., Edward, D., & Wilensky, J. T. (2005). Driving performance of glaucoma patients correlates with peripheral visual field loss. *Journal of Glaucoma*, 14(2), 145-150. Retrieved from http://journals.lww.com/glaucomajournal/Abstract/2005/04000/Driving_Performance_of_Glaucoma_Patients.11.aspx

Szlyk, J. P., Pizzimenti, C. E., Fishman, G. A., Kelsch, R., Wetzel, L. C., Kagan, S., & Ho, K. (1995). A comparison of driving in older subjects with and without age-related macular degeneration. *Archives of Ophthalmology*, 113(8), 1033-1040. doi: 10.1001/archopht.1995.01100080085033

- Taylor, J., Chadwick, D., & Johnson, T. (1996). Risk of accidents in drivers with epilepsy. *Journal of Neurology, Neurosurgery and Psychiatry*, 60, 621-627. doi: 10.1136/jnnp.60.6.621
- Torpey, S. E. (1986). *Licence re-testing of older drivers* (Report No. 91/21). Melbourne, Australia: Road Traffic Authority. Retrieved from <http://trid.trb.org/view.aspx?id=1195388>
- Tuokko, H., Tallman, K., Beattie, B. L., Cooper, P., & Weir, J. (1995). An examination of driving records in a dementia clinic. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, 50B(3), S173-S181. doi: 10.1093/geronb/50B.3.S173
- Vance, D. E., Roenker, D. L., Cissell, G. M., Edwards, J. D., Wadley, V. G., & Ball, K. K. (2006). Predictors of driving exposure and avoidance in a field study of older drivers from the state of Maryland. *Accident Analysis and Prevention*, 38(4), 823-831. doi: 10.1016/j.aap.2006.02.008
- Verhagen, P. (1995). Liability of older drivers in collisions. *Ergonomics*, 38(3), 499-507. doi: 10.1080/00140139508925121
- Vernon, D. D., Diller, E. M., Cook, L. J., Reading, J. C., Suruda, A. J., & Dean, J. M. (2002). Evaluating the crash and citation rates of Utah drivers licensed with medical conditions, 1992-1996. *Accident Analysis and Prevention*, 34(2), 237-246. doi: 10.1016/S0001-4575(01)00019-7
- Viano, D. C., Culver, C. C., Evans, L., & Frick, M. (1990). Involvement of older drivers in multivehicle side-impact crashes. *Accident Analysis and Prevention*, 22(2), 177-188. doi: 10.1016/0001-4575(90)90068-V
- Viano, D. C., King, A. I., Melvin, J. W., & Weber, K. (1989). Injury biomechanics research: An essential element in the prevention of trauma. *Journal of Biomechanics*, 22(5), 403-417. doi: 10.1016/0021-9290(89)90201-7

- Wallace, R. B., & Retchin, S. M. (1992). A geriatric and gerontologic perspective on the effects of medical conditions on older drivers: Discussion of Waller. *Human Factors*, 34(1), 17-24. doi: 10.1177/001872089203400103
- Walsh, J. M., Gier, J. J., Christopherson, A. S., & Verstraete, A. G. (2004). Drugs and driving. *Traffic Injury Prevention*, 5(3), 241-253. doi: 10.1080/15389580490465292
- White, J., Thompson, C., Turner, H., Dougherty, B., & Schmidt, D. C. (2011). WreckWatch: Automatic traffic accident detection and notification with smartphones. *Mobile Networks and Applications*, 16(3), 285-303. doi: 10.1007/s11036-011-0304-8
- Whitehead, B. J., Howie, L., & Lovell, R. K. (2006). Older people's experience of driver licence cancellation: A phenomenological study. *Australian Occupational Therapy Journal*, 53(3), 173-180. doi: 10.1111/j.1440-1630.2006.00564.x
- Windsor, T. D., & Anstey, K. J. (2006). Interventions to reduce the adverse psychosocial impact of driving cessation on older adults. *Clinical Interventions in Aging*, 1(3), 205-211. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2695172/>
- Windsor, T. D., Anstey, K. J., Butterworth, P., Luszcz, M. A., & Andrews, G. R. (2007). The role of perceived control in explaining depressive symptoms associated with driving cessation in a longitudinal study. *The Gerontologist*, 47(2), 215-223. doi: 10.1093/geront/47.2.215
- Wong, I. Y., Smith, S. S., & Sullivan, K. A. (2012). The relationship between cognitive ability, insight and self-regulatory behaviors: Findings from the older driver population. *Accident Analysis and Prevention*, 49, 316-321. doi: 10.1016/j.aap.2012.05.031
- Wood, J. M. (2002a). Age and visual impairment decrease driving performance as measured on a closed-road circuit. *Human Factors*, 44(3), 482-494. doi: 10.1518/0018720024497664

- Wood, J. M. (2002b). Aging, vision and driving. In *Transcript of proceedings: Mobility and safety of older people conference, August 2002, Melbourne* (pp. 327-343). Melbourne, Victoria: Australian College of Road Safety.
- Wood, J. M., & Carberry, T. P. (2006). Bilateral cataract surgery and driving performance. *British Journal of Ophthalmology*, 90(10), 1277-1280. doi: 10.1136/bjo.2006.096057
- Wood, J. M., & Troutbeck, R. (1994). Effect of visual impairment on driving. *Human Factors*, 36(3), 476-487. doi: 10.1177/001872089403600305
- Wood, J. M., Worringham, C., Kerr, G., Mallon, K., & Silburn, P. (2005). Quantitative assessment of driving performance in Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, 76(2), 176-180. doi: 10.1136/jnnp.2004.047118
- Yassuda, M. S., Wilson, J. J., & Mering, O. V. (1997). Driving cessation: The perspective of senior drivers. *Educational Gerontology*, 23(6), 525-538. doi: 10.1080/0360127970230603
- Zesiewicz, T. A., Cimino, C. R., Malek, A. R., Gardner, N., Leaverton, P. L., Dunne, P. B., & Hauser, R. A. (2002). Driving safety in Parkinson's disease. *Neurology*, 59(11), 1787-1788. doi: 10.1212/01.WNL.0000035636.83680.C6
- Zhan, J., & Vrkljan, B. (2011). *Exploring factors that influence vehicle purchase decisions of older drivers: Where does safety fit?* Paper presented at the Sixth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Lake Tahoe, CA. Retrieved from http://drivingassessment.uiowa.edu/sites/default/files/DA2011/Papers/016_ZhanVrkljan.pdf
- Zhang, J., Fraser, S., Lindsay, J., Clarke, K., & Mao, Y. (1998). Age-specific patterns of factors related to fatal motor vehicle traffic crashes: Focus on young and elderly drivers. *Public Health*, 112(5), 289-295. doi: 10.1038/sj.ph.1900485

Zwerling, C., Peek-Asa, C., Whitten, P. S., Choi, S. W., Sprince, N. L., & Jones, M. P. (2005). Fatal motor vehicle crashes in rural and urban areas: Decomposing rates into contributing factors. *Injury Prevention*, 11(1), 24-28. doi: 10.1136/ip.2004.005959

Appendices

Appendix A

The Driving Patterns Questionnaire.

Background

- 1) What is the postcode of your home residence? _____ (postcode)
- 2) What is your age in years? _____ (number of years)
- 3) Are you male or female? Male Female
- 4) What is the highest level of education that you have completed?

<input type="checkbox"/> Some Secondary or High School	<input type="checkbox"/> Year 12
<input type="checkbox"/> Trade/Technical College	<input type="checkbox"/> Certificate or Diploma
<input type="checkbox"/> University Degree	<input type="checkbox"/> Postgraduate Degree
- 5) Do you hold a valid driver's licence for a car? Yes No
- 6) Have you driven a car in the last month? Yes No

Driving Importance

Indicate how much you agree with the following statements by placing the appropriate number in the space provided in the right hand margin.

1 ----- 2 ----- 3 ----- 4

strongly disagree agree strongly agree

- 7) Driving is important for accessing necessary services, such as general practitioners, supermarkets, etc. _____
- 8) Driving is important because public transport is unavailable. _____
- 9) Driving is important because friends are unavailable to provide transport. _____
- 10) Driving is important because family are unavailable to provide transport. _____
- 11) Driving is important for independence. _____
- 12) Driving is important for community involvement and an active lifestyle. _____

Alternative Means of Transportation

13) Is convenient public transport available to...

Get you to the doctor's?	Yes	No
Get you to the supermarket?	Yes	No
Visit your friends and family?	Yes	No
Get you to social activities?	Yes	No

14) How often do you use public transport? (please tick one response):

- Never Rarely Sometimes
 Often Always

15) If you needed to stop driving what other mobility options would be available to you?

(please tick each of the appropriate response/s):

- Community transportation Public transportation
 Friends could drive me Family could drive me
 Husband/wife/partner could drive me Taxi

Other (please provide details) _____

Driving Self-Regulation

Answer the following questions by placing the appropriate number in the space provided in the right hand margin.

1 ----- 2 ----- 3 ----- 4 ----- 5
never rarely sometimes often always

16) During the past year, have you avoided driving when it is raining? _____

17) During the past year, have you avoided driving when alone? _____

18) During the past year, have you avoided reverse parallel parking? _____

19) During the past year, have you avoided making right turns across traffic? _____

20) During the past year, have you avoided driving on a freeway or high speed highway? _____

21) During the past year, have you avoided driving on high traffic roads? _____

22) During the past year, have you avoided driving in peak hour traffic? _____

23) During the past year, have you avoided driving at night? _____

24) During the past year, have you avoided driving at night in the rain? _____

25) In the last year have you reduced your amount of driving? (please circle one response):

Not at all Somewhat Reasonably Greatly

Indicate how much you agree with the following statements by placing the appropriate number in the space provided in the right hand margin.

1 ----- 2 ----- 3 ----- 4

strongly disagree disagree agree strongly agree

26) I would stop driving if my doctor recommended it. _____

27) I would stop driving if my friends and family recommended it. _____

28) I would stop driving if I did not feel confident enough. _____

29) I would stop driving if I felt that my health and driving abilities were not at a safe level anymore. _____

30) I would stop driving if I had caused a serious accident. _____

THANK YOU!

Thank you very much for taking the time to fill in this survey. Your contribution to this research is greatly valued.

It would also be greatly appreciated if you would agree to be contacted at a later date regarding participation in the other parts of this research involving measuring your driving patterns using a Global Positioning System (GPS). If you think you would like to contribute to this section of the research and go into a draw to win one of five \$50 Myer vouchers please provide your contact details below.

I _____ (Your full name) would like to be contacted regarding participation in the Global Positioning Section of this research.

Contact Details

Address: _____

Phone number: _____

Appendix B

Information sheet for the questionnaire section of the research.

Road Safety and Mobility of Older Drivers in Rural versus Urban Areas



Participant Information Sheet - Questionnaire

The Centre for Automotive Safety Research and the School of Psychology at the University of Adelaide are conducting a study into the safety and mobility of rural and urban older drivers.

James Thompson has recently spoken regarding this study at a “Years Ahead” presentation, which you attended, and has invited you to participate. This study should help identify some of the factors that could make driving safer for older drivers so that they can retain their licences and continue driving for as long as possible.

If you choose to participate in this study, you will be asked to complete a survey about your driving behaviour and habits. This will be provided to you at the “Years Ahead” presentation and should take no more than 10 to 15 minutes to complete. If you are interested, you will be provided with feedback about the final results of the study.

Participation in this study is entirely voluntary and, even if you agree to participate, you are free to withdraw at any time. All information gathered in the study will be kept completely confidential. Only group results will be reported in any publications that result from this study.

Your written consent to participate in the study will be sought before you start. This study has been approved by the Human Ethics Subcommittee of the School of Psychology, University of Adelaide. If you have any concerns or wish to discuss the study you may contact:

- Mr James Thompson from the Centre for Automotive Safety Research on 8313 5886
- Dr Matthew Baldock from the Centre for Automotive Safety Research on 8313 5887

For any concerns regarding the ethical aspects of this research, please contact the convener of the Subcommittee for Human Research in the School of Psychology:

Associate Professor Paul Delfabbro on 8313 4936

Appendix C

Consent form for the questionnaire section of the research.

Project Title: Road Safety and Mobility of Older Drivers in Rural versus Urban Areas Consent Form: For Questionnaire Section Only

Mr J.P. Thompson	PhD Student, Centre for Automotive Safety Research, The University of Adelaide
Dr M.R.J. Baldock	Investigator, Centre for Automotive Safety Research, The University of Adelaide
Prof J.L. Mathias	Co-Investigator, School of Psychology, The University of Adelaide
Dr L.N. Wundersitz	Co-Investigator, Centre for Automotive Safety Research, The University of Adelaide

1. The nature and purpose of the research project has been explained to me and is summarized on an information sheet. I understand it, and agree to take part.
2. I understand that I may not directly benefit from taking part in the study.
3. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
4. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.
5. I have had the opportunity to discuss taking part in this investigation with a family member or friend.
6. I am aware that I should retain a copy of this consent form, when completed, and the attached information sheet.

Name of participant:

Signed: Dated:

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed (Investigator): Dated:

I would be willing to be contacted regarding future studies on related topics. I understand that this does not commit me to take part in such studies:

Signature of participant: Dated:

I would like feedback regarding the final results of this study: Yes No

Appendix D

The Travel Diary.

Participant Number: _____

Contact Details: _____

Multiple Drivers: Yes No **Odometer Reading - Start:** _____ **End:** _____

Date	Driver	Start Location	Destination	Purpose	Start Time	End Time

Testing Began: _____ **Date** _____ **Time** _____

Testing Ended: _____ **Date** _____ **Time** _____

Appendix E

Feedback questions relating to the acceptability to the participants of the data collection processes used in Study 4 (Chapter 6).

I found that taking part in this study was easy.

Strongly Agree Agree Disagree Strongly Disagree

If you disagree, why? (Please specify) _____

I was not bothered by being called up each day and having to report my driving.

Strongly Agree Agree Disagree Strongly Disagree

If you disagree, why? (Please specify) _____

I was not bothered by having the GPS device in my car.

Strongly Agree Agree Disagree Strongly Disagree

If you disagree, why? (Please specify) _____

The GPS device did not affect the normal process of driving my car.

Strongly Agree Agree Disagree Strongly Disagree

If you disagree, in what way? (Please specify) _____

Did you change your normal driving routines in any way because you knew that the GPS device was in your car?

Not at all Somewhat Greatly

If you did, in what way? (Please specify) _____

While you were driving, did you tend to forget that the GPS device was in your car?

Not at all Somewhat Greatly

What other feedback about taking part in the study do you have? (Please specify) _____

Appendix F

Information sheet for the cognitive screening, Travel Diary and GPS tracking section of the research.

Road Safety and Mobility of Older Drivers in Rural versus Urban Areas



Participant Information Sheet - GPS

The Centre for Automotive Safety Research and the School of Psychology at the University of Adelaide are conducting a study into the safety and mobility of rural and urban older drivers. James Thompson has recently spoken regarding this study at a “Years Ahead” presentation, which you attended, and has invited you to participate. This study should help identify some of the factors that could make driving safer for older drivers so that they can retain their licences and continue driving for as long as possible.

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If you choose to participate in this study, you will be asked to complete a survey relating to your memory and thinking. This should take no more than 10 to 15 minutes to complete and will be provided to you at your home at a specified date. You will be given a Global Positioning System (GPS) device to use whenever you drive for a period of one week in order to measure the amount of driving you do. Instructions on how to operate the device will be supplied. During this week you will also receive a phone call daily from the investigator to ask you about your travel details for the previous day. If you are interested, you will be provided with feedback about the final results of the study.

Participation in this study is entirely voluntary and, even if you agree to participate, you are free to withdraw at any time. For your valued involvement you will be entered into a draw to win one of five \$50 Myer vouchers. All information gathered in the study will be kept completely confidential. Only group results will be reported in any publications that result from this study.

Your written consent to participate in the study will be sought before you start. This study has been approved by the Human Ethics Subcommittee of the School of Psychology, University of Adelaide. If you have any concerns or wish to discuss the study you may contact:

- Mr James Thompson from the Centre for Automotive Safety Research on 8313 5886
- Dr Matthew Baldock from the Centre for Automotive Safety Research on 8313 5887

For any concerns regarding the ethical aspects of this research, please contact the convener of the Subcommittee for Human Research in the School of Psychology:

Associate Professor Paul Delfabbro on 8313 4936

Appendix G

Consent form for the cognitive screening, Travel Diary and GPS tracking section of the research.

Project Title: Road Safety and Mobility of Older Drivers in Rural versus Urban Areas Consent Form: Cognitive Screening Measure and GPS Tracking

Mr J.P. Thompson	PhD Student, Centre for Automotive Safety Research, The University of Adelaide
Dr M.R.J. Baldock	Investigator, Centre for Automotive Safety Research, The University of Adelaide
Prof J.L. Mathias	Co-Investigator, School of Psychology, The University of Adelaide
Dr L.N. Wundersitz	Co-Investigator, Centre for Automotive Safety Research, The University of Adelaide

1. The nature and purpose of the research project has been explained to me and is summarized on an information sheet. I understand it, and agree to take part.
2. I understand that I may not directly benefit from taking part in the study.
3. I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
4. I understand that I can withdraw from the study at any stage and that this will not affect me in any way.
5. I have had the opportunity to discuss taking part in this investigation with a family member or friend.
6. I am aware that I should retain a copy of this consent form, when completed, and the attached information sheet.

Name of participant:

Signed: Dated:

I certify that I have explained the study to the volunteer and consider that he/she understands what is involved.

Signed (Investigator): Dated:

I would be willing to be contacted regarding future studies on related topics. I understand that this does not commit me to take part in such studies:

Signature of participant: Dated:

I would like feedback regarding the final results of this study: Yes No