Vehicle Safety and Older Occupants

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J. Charlton, B. Fildes, D. Andrea, Vehicle Safety and Older Occupants, Gerontechnology 2002; 1(4): 274 - 286. This article reviews recent scientific literature relating to vehicle design and the safety of older road users. The review describes the protection offered by recent technologies and features as well as future vehicle design recommendations. Recent research has identified that many older people are not well informed about vehicle safety issues and do not consider safety as a high priority when purchasing vehicles. Crash statistics suggest that older drivers are not involved in a large number of crashes, but when figures are adjusted for their shorter travel distances, it is clear that they are over-represented in serious injury and fatal crashes compared with younger drivers. Much of this risk can be attributed to their vulnerability or lower injury tolerance once involved in a crash. Compared with younger occupants, older vehicle occupants who sustain injuries, particularly to the chest, are likely to experience more serious consequences and require longer recovery times. The review highlights the need for better vehicle safety design to protect older occupants and better promotion of the benefits of vehicle safety amongst older road users.

Keywords: ageing, vehicles, safety features

As the population ages, there is a growing awareness of the need for vehicle safety to suit the older occupant. The ageing process makes older people more vulnerable to injury. It takes less energy to produce tissue damage and disruption, and their skeletal structures are more easily damaged through bone loss. Coupled with pre-existing health conditions, these factors tend to exaggerate the consequences of any assault. In short, there is a greater need to improve the crashworthiness of vehicles to provide better protection for older drivers in the event of a crash.

Until recently, vehicle designers predominantly have focused their designs around young adult anthropometry and performance, which means that often the ergonomic specifications of modern vehicles do not necessarily take account of the needs of older people. There is now a large body of literature describing changes in physical and performance characteristics across the adult age span, yet this research has been largely ignored in the design of vehicles. One recent exception, worthy of comment is 'The Third-Age Suit' designed by the Ford motor vehicle manufacturer in the United States. The suit simulates some of the functional limitations associated with ageing to raise the awareness of ageing among their young designers[1]. Designers wear this suit as they design the vehicle to assist them in accommodating the needs of the older driver.

The immense buying power of the older population makes them a key target group for the automotive industry. This marketing niche is likely to drive the development of specific safety designs over the next few decades. Safety is now thought to be a powerful factor in both buying and selling cars. In the past few years, there has been a significant increase in consumer interest in safety performance of cars, which has resulted in many car manufacturers highlighting the safety features of their products to boost sales. The level of demand for safer cars is likely to vary from country to country but in most 'mature' markets, a significant and growing safety demand exists. Consumer pressure has come about largely as a result of much publicised crash test results in motoring magazines and secondary safety assessments in consumer magazines. For example, European surveys of consumer demand have indicated that the public considers safety to be high on the list of desirable features in a car. Zeidler, Kullgren, Fildes, Morris, and O'Neill cite the findings of the Lex Report on Motoring showing that fifty-two percent of people thought that safety features would be particularly important when they next bought a car[2]. However, it is likely that safety priorities as well as understanding of vehicle safety differs across different age groups. This issue is discussed in more detail below.

CRASH RISK AND INJURY OUTCOMES

Why should older people be concerned about vehicle safety? In terms of absolute numbers of crashes, there is convincing evidence that older drivers do not in fact represent a large road safety problem. In Australia and New Zealand in 1998, the number of fatal crashes for drivers aged over 65 years accounted for 16.6% and 15.7% respectively. In contrast, younger drivers accounted for 25.7% and 28% of the total fatalities respectively[3].

However, the significance of vehicle safety for older people is highlighted when crash figures are adjusted to account for the lower licensing rates and smaller distances travelled by older drivers compared to their younger counterparts. When appropriate driving exposure measures are included, crash statistics suggest a significant road trauma problem for older drivers. Recent findings show that older drivers, particularly those aged over 75 years, are more likely to be involved in a serious injury crash per kilometre driven than other age groups[4].

Further, fatality data from 1998 demonstrate that drivers in Australia over 75 years had a much higher risk of being killed per kilometre travelled compared to other adult age groups. The relative risk of different driver groups being killed in a crash on Australian and New Zealand roads is illustrated in Figure 1.

THE AGEING POPULATION, MOBILITY AND SAFETY

Older driver safety is likely to become a bigger issue in the years ahead, in part as a consequence of the increased number of older, potentially more mobile, drivers in the community. Australia, like most western societies, predicts substantial changes in the proportion of older persons in the foreseeable future as the current population ages[5]. The proportion of persons aged 65 years and older in the Australian community is predicted to increase from 11.1% in 2001 to 24.2% in 2051[5]. Recent predictions also suggest that there will be a new set of challenges for safety and mobility given the demographics of the baby-boom cohort of drivers. Members of the baby-boom generation have grown up with the car, are generally more car-dependent, have higher licensing rates, and travel longer distances by car than persons of their parents' generation.

Research in the US by Hu, Jones, Reuscher, Schmoyer and Truett[6], suggests that over the next three decades, fatal crashes could be as much as *three* times greater than at present without active intervention. Hu et al. developed a model to predict the growth in older drivers from 1995 to 2025. The model takes account of driving behaviour, population migration, personal wealth and health, infrastructure, and technological impacts in the USA. Their prediction of a 286% increase in older driver fatalities between 1995 and 2025 was predicated on four key factors: an increase in the proportion of older people in the population (82% increase for males and 46% increase for females); an increase in the distance travelled by this older group (37% increase for males and 52% increase for females); an increase in the number of licensed older drivers (14% increase for males and 34% increase for females); and a decrease in their crash risk (33% decrease for males and 31% decrease for females). Using Hu et al.'s model, Fildes, Fitzharris, Charlton and Pronk[7] demonstrated a similar pattern for the Australian context, with a predicted increase of more than 280% in driver fatalities by the year 2025, compared to 1995. This will present a major challenge for the safety of older road users in future years. Clearly there is a need for a stronger awareness of and commitment to safety issues affecting older road users amongst vehicle designers, road engineers, and policy-makers as well as the older road users themselves.

Older driver crash types

Numerous studies indicate that the predominant casualty crash type for older drivers is skewed towards crashes involving complex road environments or high cognitive workload[8]. Clarke, Forsyth and Wright[9] modelled behavioural factors in intersection accidents by coding events, road environment characteristics and driver demographics using police data from Nottinghamshire, UK. The typical crash of the older driver at an intersection involved the following characteristics: turning; a high speed limit; waiting for a gap in traffic; and a failure of observation. This description is supported by the results of several studies including recent research by McGwin and Brown[10], and Pruesser, Williams, Ferguson, Ulmer and Weinstein[11]. These studies found older drivers were over-represented in crashes at intersections and/or involving the failure to yield the right of way, par-

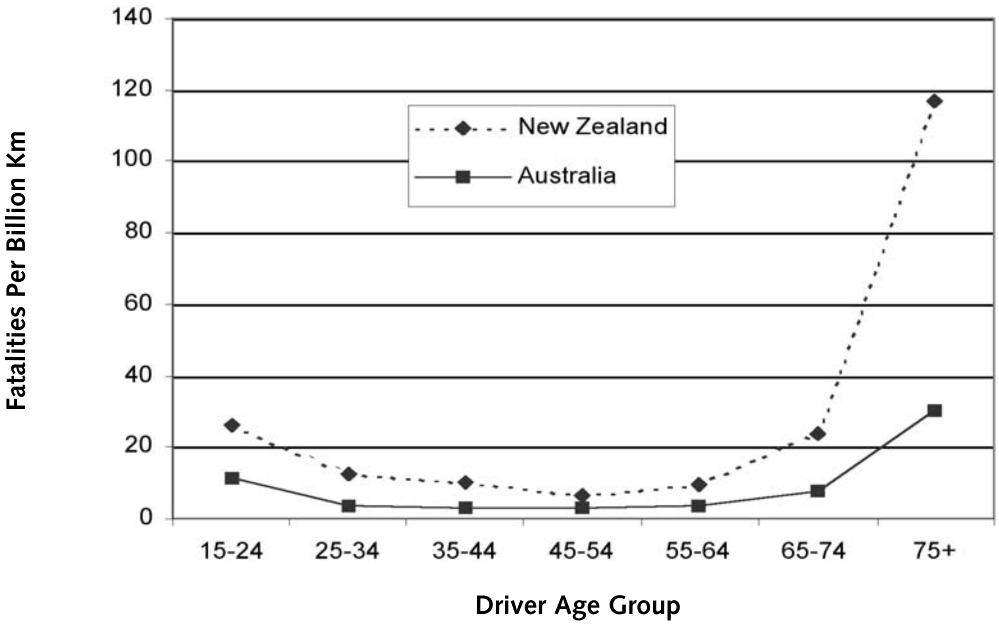

Figure 1. 1998 Driver Fatality Rate per Distance Traveled in Australia and New Zealand[3]

ticularly at stop sign-controlled or uncontrolled locations. Crashes occurring while turning and changing lanes were also more common amongst older drivers. Pruesser et al.[11] indicated that compared to 40-49 year olds, drivers aged 65-69 were 2.26 times more at risk of a fatal multi-vehicle crash at an intersection but only 1.29 times more at risk in all other situations. Drivers aged 85 and older were 10.62 times more at risk in multi-vehicle intersection accidents compared with 3.74 times for all other crash situations.

Larsen and Kines[12] conducted a series of investigations of head on and left turn (equivalent to right turn in Australia) collisions. Six out of 17 left turn collisions involved a driver over the age of 74 years, and all were the left-turning driver. Larsen and Kines' analysis indicated that errors were made in drivers' direction of attention, detecting approaching road users, judging an appropriate time to execute the turn, or as a result of difficulty judging the distance and speed of other road users.

Andrea, Fildes, and Triggs[13-14] observed similar errors of judgement by older participants in two experimental studies. Older participants were found to be less sensitive in estimating the position of an approaching vehicle and their sensitivity reduced with higher speed approaches. In a second study, differences between older and younger participants were even more exaggerated when two approaching vehicles were presented in the visual display. This result is supported by models of crash occurrence indicating the added difficulty of heavy traffic volume for older drivers[15]. Age-related functional, cognitive, and visual impairments as well as chronic medical conditions and medications are likely to exacerbate the prevalence of these types of driving difficulties.

Older driver accident types are also more likely to be serious in nature and have more serious injury outcomes. Crashes such as those reported by Larsen and Kines[12], were likely to result in a side impact. One of the most striking results from the work of Li, Braver and Chen[16] related to older drivers and side impact crashes. Drivers aged 75 or older were 13 times more likely to die from this type of crash than the 30-59 year old age group. This result was due both to an over-involvement in side impact crashes and increased fragility given the occurrence of this type of crash.

Vulnerability of older drivers

The recent OECD report on Ageing and Transport[17] states that the most critical safety issue for older drivers and passengers relates to their increased frailty and associated increase in injury susceptibility. It is well known that the energy required to cause injury reduces as a person ages[18]. The biomechanical tolerances to injury of the older adult are generally lower than that of younger persons[19,20], primarily due to reductions in bone strength and fracture tolerance. Research has shown that fractures to the chest may be the most significant injury difference between older and younger car occupants. Older occupants may be several times more likely to sustain a life-threatening chest injury and this can occur in a relatively moderate crash[21]. The chest is clearly a vulnerable area and the major load bearing area for restraint systems as well as a major point of contact with the vehicle structure during a crash. In addition, age-related declines in physical health increase both the likelihood of a serious injury outcome among older vehicle occupants involved in a crash and prolong or prevent recovery from injuries sustained.

The frailty or fragility of older drivers and passengers can also be illustrated by a fragility index, the risk of an injury resulting in fatality. Compared with drivers aged 20-50 years, fragility increases this risk by 1.75 times for drivers aged 60 years, by 2.6 times at age 70, and over 5 times for drivers aged 80 and above[22]. Li and colleagues[16] also report similar increases in fragility with advancing age, and higher levels of fragility observed in females compared with males. They proposed that 60-95% of the increase in death rate per distance travelled for those aged 60 and over could be accounted for by increases in fragility. Marked excesses in crash involvement were observed beyond the age of 75 years but this explained only around 30-45% of the elevated risk of fatality in drivers of this age and less for drivers aged 60-74 years[16].

Types of injuries sustained by older vehicle occupants

The evidence from crash statistics clearly indicates that older vehicle occupants are likely to suffer a more severe injury outcome in the event of a crash. However, age-related differences in specific injury outcomes in vehicle crashes remain a largely unknown factor. While the studies reviewed above suggest that older drivers have distinct and different crash patterns compared to younger drivers, there is comparatively little information regarding injury patterns for specific crash types involving older adults. More research is needed on the relative protective influences of vehicle size, design, and safety features for older drivers. Notwithstanding the lack of specific data on this issue, there is an emerging interest in research into injuries to the older vehicle occupant that provides a good foundation for future in-depth investigations.

In one such investigation, Morris, Frampton, Fildes, and Charlton[23] studied UK injury data covering current model cars collected between 1992 and 2001. In total, 2,200 single impact vehicle crashes were studied with 315 cases where the driver was aged 65 years or over. Crash injuries were coded and described according to the Abbreviated Injury Scale 1990 revision (where MAIS 1 indicates a minor injury and MAIS 6 indicates an injury certain to result in a fatality). The findings showed very different injury outcomes for young compared to older drivers. Twelve per cent of older drivers were found to sustain injuries at the MAIS 4 level compared to just 2% of younger drivers and 3% of middle-aged drivers. For side impacts, older drivers also sustained significantly more injuries than younger drivers at both the MAIS 3 and MAIS 4 levels of injury severity.

The ability to recover from injuries is also dramatically reduced in older persons. Research conducted by Cunningham, Howard, Walsh, Coakley and O'Neill investigating accident severity and outcomes in road crash cases in Ireland highlighted this issue[24]. They found that older individuals involved in crashes had significantly greater surgical, medical and therapy workloads prior to discharge, significantly more serious complications, and significantly longer length of hospital stays.

While older driver real-world crashes are to date relatively understudied, results from the studies presented here highlight the need for engineering considerations to improve the safety of older vehicle occupants. There is an urgent need to conduct more in-depth investigations of the relative frequency and severity of injuries in occupants of different ages and for various configurations of crash types and vehicle design fittings. This type of analysis is critical for the advancement of engineering and other solutions specific for older occupant safety.

Awareness of vehicle safety issues

Awareness of vehicle safety is likely to be an important contributing factor in reducing crash involvement and improving injury outcomes across the community in general. Given the relatively high crash risk of older vehicle occupants and their increased risk of serious injury outcomes, the importance of vehicle safety for older people is of paramount concern. The OECD report on Ageing and Transport[17] notes that "older drivers need information on the implications of ceasing to drive, on the physical and cognitive changes experienced as part of the ageing process, and on the choice of safer vehicles" (p.112). In particular, the report highlights the importance of informing older drivers about special features to consider when choosing a car, such as seat positioning, driver and passenger restraints, power assisted devices and applications of new technology.

There is clearly much scope for improvement in awareness of vehicle safety features across all age groups of drivers. Australian National Opinion Polls (ANOP) found a continuing belief that stronger and bigger cars offered more protection, whereas smaller ones were seen as less robust[25]. In addition there was no consensus that new cars were generally any safer than older cars although new expensive cars were seen as having superior safety features. The study also reported notable age-related differences in motorists' awareness and attitudes on such issues as general crashworthiness and airbags effectiveness. For example, when asked about *what aspects or features of a car help to make it safe in a crash*, only 51% of drivers aged over 55 years spontaneously responded that specific safety features years (such as airbags and seatbelts) were important, compared to over 75% of drivers in the age groups 18-24 and 25-33 years. Interestingly, only about 17-20% of all age groups responded that accident prevention features were important. In addition, while nearly 20% of the 18-24 year olds identified impact absorption (e.g. crumple zone), only 9% of the over 55 year age group responded that this was a feature that helps make a car safe in a crash.

Table 1. Major airbag concerns amongst Australian motorists of all ages[25]

Concern	%
General	
Can cause injuries	27
Go off too easily	21
Not convinced of benefits	14
Cost to refit	11
Purchase cost	32
Wanting airbag in next vehicle	
Total	48
Safer, more secure	27
Reduce injury, head	8
Save your life	6

Our own research on older adults and vehicle safety concurs with these findings[26]. More older participants in this study rated the *handling of the vehicles* as more important than *safety* when purchasing a vehicle. The study also revealed two main areas of misinformation amongst older people: airbags and vehicle structure including the value of modern crumple zone design.

The ANOP survey also found that consumers had some misgivings about airbag effectiveness in vehicles[25]. This survey showed that even amongst those who wanted an airbag in their vehicle, the credibility of airbags had been undermined by some anecdotal evidence (primarily from the US). The major concerns amongst motorists of all ages are shown in Table 1.
Overall, among Australian motorists, the concept of airbags is a vexed and often misunderstood issue. Fewer than half of those surveyed said that they wanted an airbag in their next car. Only 22-25% of respondents aged 18-54 years and 15% of those over 55 years said that they wanted an airbag "a great deal". A recent story conveyed to one of the authors helps to illustrate how misinformed some consumers are about SRS airbags. '*You hear all these stories about them (airbags) – like whenever you drive with your arms crossed over or if the airbag goes off, it will break your nose. And then it can push the bones in your nose up into your brain and it will kill you. That's the instructions they give you whenever you drive a car with an airbag*' (from a woman in Melbourne)

VEHICLE SAFETY FEATURES AND THEIR RELEVANCE FOR OLDER OCCUPANTS

These misconceptions need to be addressed by better publicity to enhance awareness about airbags and their protective benefits. Airbags that are sold in Australia are Supplementary Restraint Systems or SRS Airbags. They differ from their US counter-

parts (which are designed as Primary Restraint Airbags) in three fundamental ways: They are used as *a supplement* to the seat belt rather than as a replacement and are less aggressive than US bags. This means the force with which they deploy in a crash is much less than US designed airbags.
They are usually smaller in size and have tether straps fitted inside which ensures they are less likely to impact on the occupant during deployment.
Third, they are deployed at much higher crash severity thresholds again to minimise the likelihood of the airbag causing unnecessary damage to the occupants while still providing the level of protection necessary to reduce injury.

Older people are much more susceptible to chest and rib damage than younger people. While head injury is the primary cause of death for younger adults, older occupants are more likely to die from a chest injury[27]. Researchers at the University of Michigan Hospital reported that 86% of drivers and passengers aged 60 years and older who died suffered a chest injury as their principal cause of death. The need for these people to have the added advantage of an airbag in a crash is obvious from these findings. Moreover, new developments in dual-stage airbags to minimise aggressive airbag contact in moderate crashes may be especially relevant for older occupant protection[17].

Morris, Barnes, Fildes and Bentivegna showed that the benefits of an SRS airbag in Australian vehicles was a significant reduction in serious head, neck and chest injuries to occupants in airbag deployed vehicles and fewer contacts with hazardous objects inside the vehicle[28]. They estimated that the airbag resulted in almost a 50% reduction in occupant harm in a crash.

Seat belts

Seat belts have provided considerable benefits to motorists over the years in reducing death and injury on our roads and are still quite rightly considered to be the primary restraint within a vehicle. Their benefits at reducing death in crashes was outlined comprehensively by Evans[22] (in his book *Traffic Safety and the Driver*). who listed the life saving of a restrained over an unrestrained driver as: (a) Lap/shoulder belt – 41% (±4); (b) Shoulder alone – 29% (±8); (c) Lap belt alone – 18% (±9); (d) Lap/shoulder + airbag – 46% (±4).
Evans noted that the benefits from seat belts came from both reducing occupant ejection from the car during the crash as well as from reducing occupant contact within the car.

Seat belts, however, do cause some injury themselves. Research by Fildes, Lane, Lenard and Vulcan revealed that seat belt injuries were the second-most common source of injury among a hospitalised sample of crash victims in Australia behind steering wheel contact, although these injuries were usually minor and were not significant among serious injures[29]. There is scope for manufacturers to improve seat belt protection and

Table 2 Absolute relative injury risk for drivers in vehicle-to-vehicle side impacts[33]*

Front impacted vehicle		Mini	Small	Medium	Large	4WD
Side	Mini	2.0:1	2.1:1	2.1:1	2.2:1	2.4:1
Impacted	Small	1.7:1	1.7:1	1.8:1	1.8:1	2.0:1
Vehicle	Medium	1.7:1	1.7:1	1.8:1	1.8:1	2.0:1
	Large	1.5:1	1.5:1	1.5:1	1.6:1	1.7:1
	4WD	1.4:1	1.4:1	1.4:1	1.5:1	1.6:1

**Relative injury risk adjusted to control for age and sex of the driver and speed zone of the crash. Risk of injury expressed as a ratio of side to front.*

occupants should ensure that the belt is properly fitted over their pelvis and shoulder.

Nevertheless, with the increased likelihood of an older person being incapacitated from a relatively minor chest injury[27] there is a greater potential for harm among the older population. They were more than twice as likely to suffer a rib injury than their younger counterparts, confirming the greater need for older people to have the added benefit of an SRS airbag as well as a properly fitted seat belt. Advances in seat belt design such as intelligent restraint systems capable of adjusting for lighter occupants are also likely to offer better protection for older adults[17].

Vehicle mass

The one most salient safety feature of a car is its mass in a collision with another vehicle. A higher mass vehicle in a two-car collision at similar speeds will experience a lower crash severity than the lighter vehicle because of the physics of the situation. For example, if two cars of 1000 and 1500kg travelling in opposite directions at the same speed were to collide head on, the lighter car would experience a crash that was 50% more severe than the heavier car, based on mass difference alone.

Cameron, Mach and Neiger demonstrated the positive benefits of vehicle mass based on real world crash data in several states in Australia as shown in Figure 2. This shows that vehicle crashworthiness clearly improves (fewer injuries and severe injuries per 100 crashes) as the vehicle mass increases.
While there are many other issues to consider when purchasing a new car for older men and women, nevertheless, the safest car for an older person in a crash is one that is large. It is commonly recommended, therefore, that when purchasing a new vehicle, one should look to buy as large a car as is possible.

Vehicle aggressivity

Of growing concern is the issue of the aggressivity of a car in a collision with another, especially in a side impact collision. The role of stiffness in promoting injuries in side

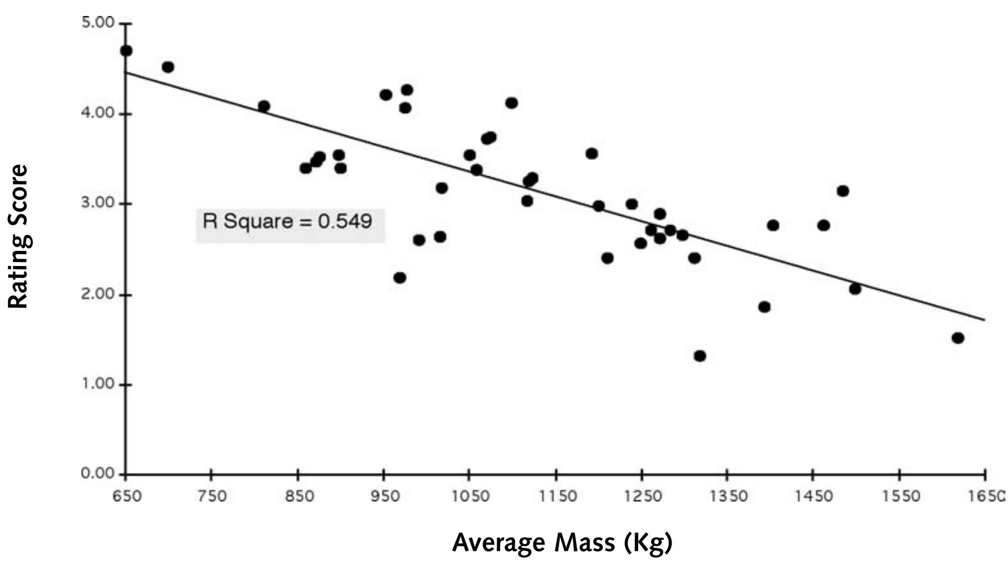

Figure 2. Crashworthiness rating score (higher score indicates less crashworthy) vs average mass of car model[30]

impacts is still a rather contentious issue. There is considerable current debate in vehicle compatibility research as to whether the mass, stiffness or geometric structure of the striking vehicle in a side impact collision is the most pertinent feature in injury causation. Some have argued that mass is dominant[31] while others argue that geometry is more relevant[32]. Since most of the injury occurs very early in the crash sequence, a stiffer structure is considered to be of lesser relevance than either the mass (impact force) or the geometry of the striking object.

An analysis of car to car crashes carried out by Les, Fildes, Seyer and McFadden compared the relative risk of injury by vehicle size and type in frontal and side impact collisions involving survivors of crashes[33]. They reported that in all cases, the smaller the car, the greater the increased risk of injury to the driver, proportional with the difference in mass category. In side impacts, the risk of injury to drivers also generally increased as vehicle mass reduced (Table 2). Their findings for 4WD vehicles seemed much smaller than was predicted which they explained by the small number of cases in this category and the large mass variation within the 4WD category. Given the high front of many of these vehicles and their rather stiff front structures, they must invariably inflict greater harm to occupants of passenger cars they collide with than similar mass passenger cars. The growing proportion of these vehicles on our roads that have very little relevance for city travel is a concern for everyone, especially older motorists.

Vehicle age

The Australian vehicle fleet is quite old with a mean age around 11 years and a reasonable proportion beyond 25 years old. With the advent of regulations and more attention given to safety, more recent vehicles have a much improved safety record than do older ones. This is explained by improved vehicle structures, better safety technology, a rigid occupant compartment, and other modern improvements. The relative safety of old and new vehicles is clearly shown in Figure 3.

The findings of Newstead, Cameron and Le

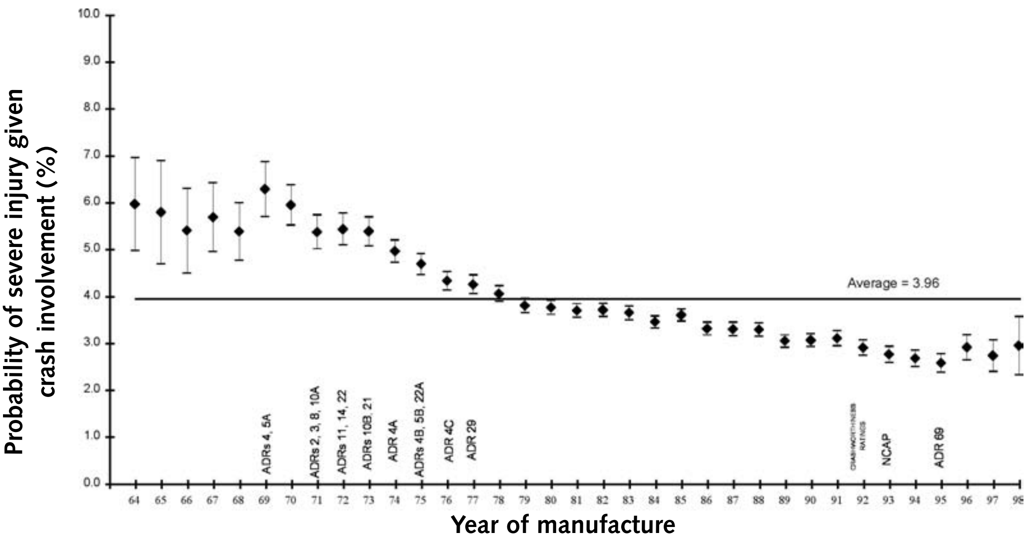

Figure 3. By year of manufacture[34]. NCAP means New Car Assessment Program.
Australian Design Rules (ADR) listed in Figure 3: ADR 2: 'anti-burst' door hatches; ADR 3: strengthened seat anchorages; ADR 4: seat belts fitted in front seats; ADR 4A: improved seat buckles; ADR 4B: inertia reel seat belts fitted in front seats; ADR 4C: dual-sensing locking retractor inertia reel seat belts; ADR 5A: seat belt anchorage points for front seats; ADR 5B: improved location of seat belt anchorages; ADR 8: safety glass in windscreens and windows; ADR 10A: 'energy-absorbing' steering columns; ADR 10B: steering columns with limited rearward displacement; ADR 11: 'padded' sun visors; ADR 14: 'breakaway' rear vision mirrors; ADR 2: 'padded' instrument panels; ADR 22: head restraints; ADR 22A: minimum height adjustable head restraints; ADR 29: side door strength.

suggest that it would be advantageous for all people but particularly older motorists where possible to trade up to a more recent vehicle and take advantage of the inherent safety offered in newer cars[34].

New safety features

Modern passenger cars are constantly being fitted with new and safer technologies such as side airbags, new braking systems (eg; ABS), intelligent cruise controls and headway monitors. While many of these devices are still to be evaluated under real world conditions, they do offer promise to improve the crashworthiness of the vehicle and also help to avoid the crash in the first instance.

Of some concern, though, are their benefits for older motorists in particular. This is especially so for devices that need a human response. ABS braking systems for instance provide a quite different pedal response to the normal brake pedal, which can cause a driver to relax the pressure on the pedal during heavy braking. While this is potentially a problem for all drivers, it is likely to be even more a problem for older drivers who are less able to understand the system and the need to react appropriately. There is clearly a strong need for urgent research to understand how the older motorist responds to these new technologies.

INTELLIGENT TRANSPORT SYSTEMS

The potential of intelligent transport systems to prevent crashes involving older drivers should also be noted. However, older drivers are most likely to suffer the effects of poorly designed ITS applications[35]. Some ITS devices require additional attentional resources and these capacities are already limited in older drivers. Systems that increase the information processing load of the driver or increase the complexity of driving generally have been found to compromise the performance of the older driver[17]. ITS applications need to be specifically tailored to older driver characteristics in order to offer improved crash avoidance or simplify the driving task. Regan, Oxley, Godley and Tingvall identified a number of ITS applications, currently under development, that may provide the greatest potential safety benefit[36]. These include mayday systems (or emergency trauma alert systems), vision enhancement systems, rear collision warning systems and in-vehicle navigation systems. ITS applications that aid older drivers to negotiate intersections and other complex traffic manoeuvres are currently being explored and could be expected to generate significant safety benefits[36]. The behavioural adaptations to such systems over time or the willingness to use and purchase these items are poorly understood at present. Research into technologies that account for the limitations and capacities of older drivers and the acceptance of these ITS applications is urgently required.

OTHER SAFETY FEATURES

A number of other safety features of cars relevant for older drivers are worthy of note:

(a) Centre high-mounted stoplights are now standard on all new cars (mandatory in Australia since 1995). They play an important role in providing visual information about the status of the vehicle ahead and are therefore likely to enhance driver safety. Around 60% of motorists over the age of 55 years own a vehicle that is 6 or more years old[25]. Thus, many of these vehicles predate the standard fitting of centre-mounted brake lights. The benefit of retro-fitment of such units should be promoted amongst these motorists.

(b) Handling characteristics of a vehicle are important for controlling the vehicle on the road and power steering and automatic transmissions make it easier for people with less strength to maintain proper control of their vehicles at all times[17].

(c) Cruise control can be an advantage for ensuring that the vehicle does not exceed the speed limit on rural roads. They can be used in low-density urban areas too but their use in high-density traffic is problematic.

(d) It is always important to maintain good visibility when driving. Ninety-five percent of the input for driving comes from the visual system and hence clear windscreens are imperative. Window tinting can be a problem at night and for drivers who have difficulty with low contrast vision and is not recommended generally for older people.

(e) Leaving the headlights on during the day (Daylight Running Lights) can be an advantage for other motorists and pedestrians to see an oncoming car. Evidence from Scandinavia and Canada suggests they do lead to a reduction in crashes in these countries.

CONCLUSIONS

There is little doubt that with an ageing population, the number of older drivers involved in road crashes will increase substantially in the years ahead. It is important, therefore, that vehicle manufacturers improve the usability of vehicles and occupant protection systems to suit the specific needs and vulnerabilities of older adults. In addition, there is a need to promote better awareness and understanding of the benefits of specific vehicle safety features amongst older motorists.

A number of vehicle safety features relevant to older occupants have been reviewed here. Most importantly, a modern, large, and safe vehicle is imperative for older people, as they are frailer than their younger counterparts and less resilient to trauma generally. Ensuring that the vehicle has the latest safety technology is important. In frontal collisions, seat belts and driver and passenger airbags are particularly significant in reducing serious injury of older, more frail occupants. The vulnerability of older occupants to serious chest injury supports a case for the development of improved or 'smart' restraint technology designed to match the older occupant's biomechanical tolerances. Similarly, the next generation of airbags that sense the size and position of occupants and inflate accordingly hold considerable promise for improving the injury outcome of older occupants involved in a crash. Vehicle designs incorporating greater ability to adjust seating and pedal positions could additionally enhance the outcome for older drivers involved in a crash. The need for enhanced protection in side impact crashes is also evident, given the poor injury outcomes for older adults involved in this type of crash.

This review highlighted an urgent need for more investigative crash research to describe the association between particular crash types, vehicle design features, and injury outcomes for older occupants. These kinds of data will guide the development of better engineering considerations to improve the safety of older drivers and offer better crash protection for future generations of older adults.

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References

1. Lupton F. The 3rd age suit. Paper presented at the Aging and Driving Symposium, Association for the Advancement of Automotive Medicine, Des Plaines, IL, 2001 February 19-20, 2001

2. Zeidler F, Kullgren A, Fildes BN, Morris A, O'Neill B. Problems in defining safety and consequences for consumer information. SARAC Report CEA Secretariat No. S1-7_06f. Brussels: European Commission; 2001
3. Fildes B, Pronk N, Langford J, Hull M, Frith B, Anderson R. Model Licence Re-assessment Procedure for Older and Disabled Drivers. Austroads Report No. AP-176/00. Canberra: Austroroads; 2000
4. Diamantopoulou K, Skalova M, Dyte D, Cameron M. Crash risks of road user groups in Victoria. Victoria. Monash University Accident Research Centre Report No.88. Melbourne: Monash University; 1996
5. Australian Bureau of Statistics (ABS) Older people: A social report. Cat. No. 4109.0. Canberra: ABS; 1999
6. Hu P, Jones D, Reuscher T, Schmoyer R, Truett T. Projecting fatalities in crashes involving older drivers. Report for the National Highway Traffic Safety Administration. Tennessee: Oak Ridge National Laboratory Tennessee; 2000
7. Fildes B, Fitzharris M, Charlton J, Pronk N. Older driver safety – A challenge for Sweden's 'Vision Zero'. In: [editors to be added], editors, Proceedings of the Australian Transport Research Forum, Hobart, 17-20 April; Tasmania: Tasmanian Dept of Infrastructure, Energy & Resources; 2001;
8. Fildes B, Corben B, Morris A, Oxley J, Pronk N, Brown J, Fitzharris M. Austroads Report No AP-R169/00. Canberra: Austroroads; 2000
9. Clarke DD, Forsyth R, Wright R. Behavioural factors in accidents at road junctions: The use of a genetic algorithm to extract descriptive rules from police case files. Accident Analysis and Prevention 1998; 30: 223-234
10. McGwin G, Brown DB. Characteristics of traffic crashes among young, middle-aged and older drivers. Accident Analysis and Prevention 1999; 31: 181-198
11. Pruesser DF, Williams AF, Ferguson SA, Ulmer RG, Weinstein HB. Fatal crash risk for older drivers at intersections. Accident Analysis and Prevention 1998; 30(2): 151-159
12. Larsen L, Kines P. Multidisciplinary in-depth investigations of head on and left turn road collisions. Accident Analysis and Prevention 2002; 34: 367-380
13. Andrea DJ, Fildes BN, Triggs TJ. The Sensitivity and Bias of Older and Younger Driver Judgements in Complex Traffic Environments. In: Rogerson P, Haworth N, Catchpole J, Calvert F, editors, Proceedings of the Road Safety Research, Policing & Enforcement Conference, November 2001. Melbourne. Melbourne: Conference Management Office Monash University; 2001; pp 8-14.
14. Andrea DJ, Fildes BN, Triggs TJ. The sensitivity and bias of older driver judgements in an arrival-time task. In: Kursiust, editor Proceedings of the Road Safety Research, Policing & Enforcement Conference, 2000 November. Brisbane: Centre for Accident Research and Road Safety Queensland (CARRS-Q); 2000; pp 217-222
15. Abdel-Aty MA, Radwan AE. Modeling traffic accident occurrence and involvement. Accident Analysis and Prevention 2000; 32: 633-642
16. Li G, Braver ER, Chen L. Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. Accident Analysis and Prevention 2002 In press
17. OECD Ageing and Transport: Mobility Needs and Safety Issues. Paris: OECD Scientific Expert Group; 2001
18. Augenstein J. Differences in clinical response between the young and the elderly. Paper presented at the Aging and Driving Symposium, Association for the Advancement of Automotive Medicine, 2001 February 19-20, Des Plaines, IL, USA
19. Mackay M. Occupant protection and vehicle design. Los Angeles: Association for the Advancement of Automotive Medicine Course on the Biomechanics of Impact Trauma; 1998
20. Viano DC, Culver CC, Evans L. Involvement of older drivers in multi-vehicle side-impact crashes. In: Mucha P, Mackay M, editors, Proceedings of the 33rd Annual Association for the Advancement of Automotive Medicine Conference. Baltimore: AAAM 1989; pp 337 - 352.
21. Padmanaban J. Crash injury experience of elderly drivers. Paper presented at the Aging and Driving Symposium 2001 February 19-20, Southfield, MI, USA. Des Plaines: Association for the Advancement of Automotive Medicine; 2001
22. Evans L. Traffic Safety and the Driver. New York: Van Nostrand Reinhold; 1991
23. Morris A, Frampton R, Fildes B, Charlton J. Requirements for crash protection of older drivers. Paper submitted to Proceedings of the Conference of the Association for the Advancement of Automotive Medicine, 2002, Sept 30-Oct 2, Des Plaines, IL, USA. submitted 2002.
24. Cunningham C, Howard D, Walsh J, Coakley D, O'Neill D. The effects of age on accident

severity and outcome in Irish road traffic accident patients. Irish Medical Journal 2001; 94: 169-171
25. ANOP. What motorists are thinking. Detailed report on 1997 ANOP National Survey, Canberra: ANOP Research Services, Australian Automobile Association; 1997
26. Charlton J, Andrea D, Fildes B, Morris A, Oxley J, Langford J, Johnson L. Safe Vehicle Choices for Older Adults. RACV Report. Victoria: RACV; 2002; in press
27. Alonso-Zaldivar R. Auto makers retool to fit an aging U.S. Safety: Study puts focus on protecting the growing population of older drivers. LA Times, July 31, 2000
28. Morris AP, Barnes J, Fildes BN, Bentivegna F. Effectiveness of ADR 69: A case control study of crashed vehicles equipped with airbags. Report for the Australian Transport Safety Bureau. Canberra: Australian Transport Safety Bureau; 2001
29. Fildes BN, Lane JC, Lenard J, Vulcan AP. Passenger cars and occupant injury. Report CR95. Canberra: Australian Transport Safety Bureau (formerly the Federal Office of Road Safety); 1991.
30. Cameron M, Mach T, Neiger D. Vehicle crash-worthiness ratings: Victoria 1983-90, and New South Wales 1989-90 crashes. Monash University Accident Research Centre Technical Report Clayton: Monash University; 1992
31. Prasad P. Compatibility considerations. First Informal Meeting of the European Enhanced Vehicle-Safety Committee Working Group 15 and the Motor Vehicle Safety Research Advisory Committee Vehicle Compatibility Working Group, George Washington University, Virginia Campus, USA; 1998 June 8-9
32. Hobbs CA, Williams DA, Coleman DJ. Compatibility of cars in front and side impact. Paper presented at the 15th International Technical Conference on the Enhanced Safety of Vehicles. May 13-7, Melbourne, pp. 617-624
33. Les M, Fildes BN, Seyer K, McFadden M. Vehicle compatibility: Analysis of real-world non-fatal casualty crashes. Report to the Australian Transport Safety Bureau (formerly the Federal Office of Road Safety), Canberra: Australian Transport Safety Bureau; 1999
34. Newstead SV, Cameron MH, Le CM. Vehicle crashworthiness and aggressivity ratings and crashworthiness by year of vehicle manufacture: Victoria and NSW crashes during 1987-98 and Queensland crashes during 1991-98. Monash University Accident Research Centre Report No. 71. Clayton: Monash University; 2000
35. Stamatiadi, N. IVHS and the older driver. Transportation Quarterly 1994; 48 (1), 15-22
36. Regan M, Oxley J, Godley S, Tingvall C. Intelligent Transport Systems: Safety and Human Factors Issues. RACV Report 2001. Report No 01/01. Victoria: RACV; 2001