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Older Drivers and Possibilities for Injury Avoidance

Abstract

This paper set out to examine the possibilities for injury avoidance implications for older drivers in crashes, based on crash and injury patterns among older drivers and current trends in ageing in most western societies. A number of safety technologies were identified and discussed which have potential for improving vehicle older driver crash avoidance and crashworthiness. While there were some promising estimates available of the likely benefits of this technology for improving safety, it is evident that they need to be confirmed for older drivers, given their age-related disabilities and sensory limitations. Further research is urgently required to ensure that these technologies yield safety benefits without any disbenefits for older drivers.

Introduction

As the western world ages, there is an ever-increasing interest in older driver safety. Population estimates for most of the developed countries show that by 2030, one in every four people will be aged over 65 years and by 2050, experts predict a tripling of those aged 80 or more (OECD, 2001). This report notes that the baby boom generation will live longer, be more active and lead much healthier lives than their parents, thereby adding to their longevity.

Mobility is critical for older people. Studies in the USA point to the fact that many older people stop walking before they stop driving (EBERHARD, 1996), hence, the car becomes their primary means of getting around. The ability to get about freely is important in terms of maintaining their health and preventing the onset of health problems (MAROTOLLI et al,. 2000; STUTTS et al., 2001) such as depression (FONDA et al., 2001). To be an active and contributing member of society, one has to remain mobile. Furthermore, stopping driving has been associated with needing greater levels of dependence, often requiring re-accommodation and assisted care and early death (CHIRIKOS & NESTEL, 1985).

Fatality ratios (the risk of an injury being fatal) by age group increase with age is shown in figure 1 below. UK figures show that drivers aged 20 have a “fragility index” of around 1 rising three to four fold for drivers aged 80 or more (MITCHELL, 2000). The increase is even more marked for pedestrians. Similar results are reported also among US drivers and pedestrians (EVANS, 1991).

While older drivers crash numbers tend to be relatively small today, they are over-represented in terms of serious injuries mainly because of their increased frailty. HAUER (1988) reported that the over-representation of older drivers in severe crashes was not necessarily a function of their increased likelihood of having a crash so much as their increased liability of being injured or killed, due to the disability associated with ageing. Frailty or reduced biomechanical tolerance to injury is a normal part of ageing. EVANS (1991) claimed that males are 2.3 percent more likely to die in the same severity crash for each year above 20, while for females this rises by 2.0 percent.

Given the greying of western society, though, it is inevitable that crashes involving older road users will become more frequent in the coming years. Researchers in the USA and Australia have attempted to predict what this increase is likely to be taking into account what influences older drivers’ decisions to continue to drive, and attempting to predict and understand future economic and related developments that are likely to alter historical trends in driver behaviour. Their estimates predict that the older driver safety problem will triple over the next 30 years without active intervention (HU et al., 2000; FILDES et al.,

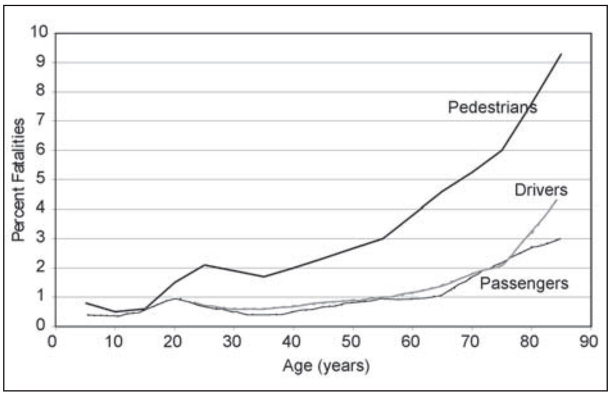

Fig. 1: Fatalities per all injuries by age and mode of travel (MITCHELL, 2000)

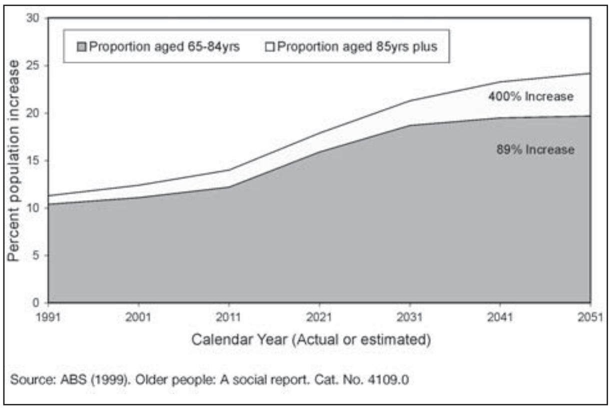

Fig. 2: Projected proportions of 65–84 year old adults and 85+ year old adults in the Australian population, 2001–2051

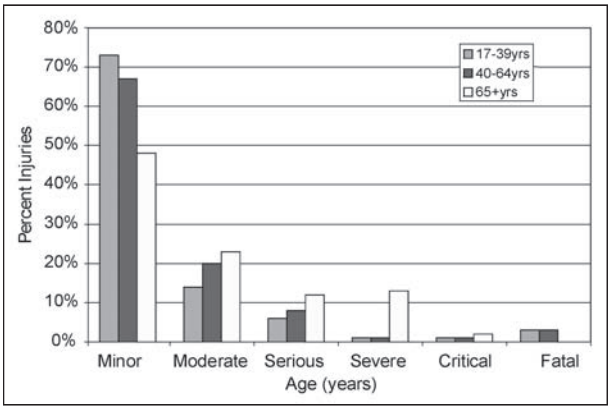

Fig. 3: Injury outcome by age – frontal crashes

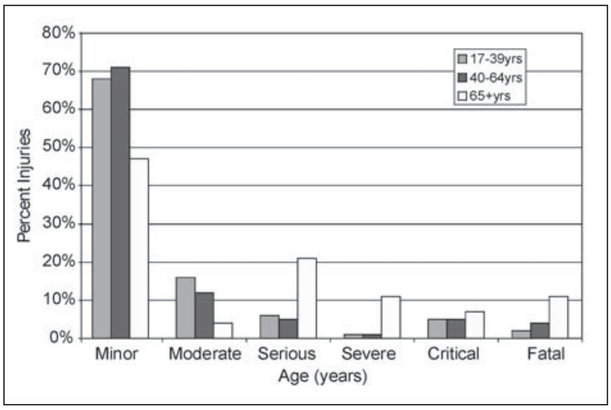

Fig. 4: Injury outcome by age – side impacts

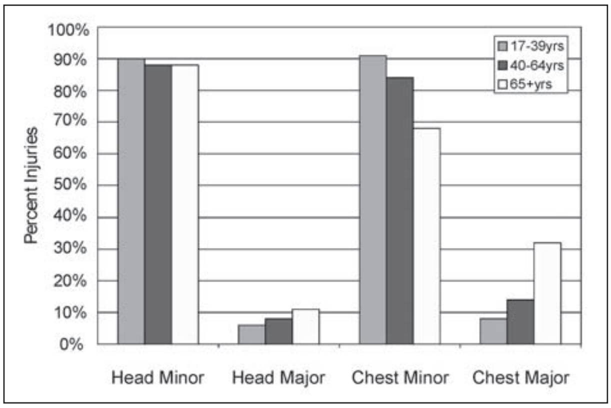

Fig. 5: Injury outcome by age – side impacts

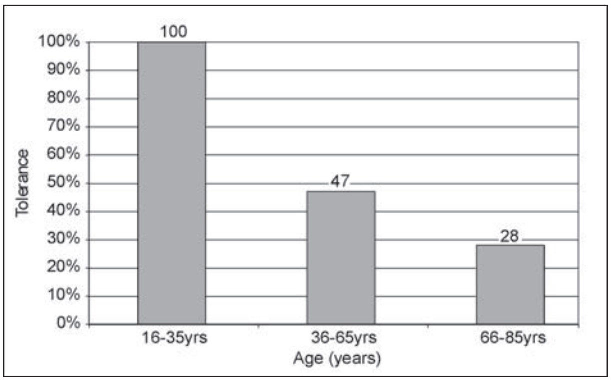

Fig. 6: Belt load tolerance (MELVIN 2001)

2001). Moreover, the biggest increase is likely to be for those aged 85 years or more.

Injuries to Older Drivers

As noted above, older drivers are much more likely to be seriously injured or killed in a collision than younger drivers because of their increased frailty. WANG et al., (1999) reported that older car occupants, 60 years and older, are twice as likely to die in a car crash, as are their younger counterparts. They also noted from their in-depth data that 86% of older occupants died from serious chest trauma and only 38% died from major head injuries (some may have died from both these injuries). The noted that 40% of those who died of a chest injury had suffered no more serious injuries than broken ribs. This is quite different for younger people where head injury is the predominant cause of death (WANG et al., 1999). They noted that seat-belts were less protective for chest injuries among the elderly.

An analysis of in-depth data collected at MUARC for predominantly survivors confirmed many of these findings. As shown in figures 3 and 4, in both frontal and side impacts after controlling for crash severity, occupants aged 65 years and above were more likely to sustain an MAIS 3+ injury than younger adults. Moreover, figure 5 shows that older occupants in side impacts were more likely to sustain a major chest injury than younger occupants and than head injuries.

MELVIN (2001) reported seat belt load tolerances by age group as shown in figure 6. He noted that those aged 36 to 65 years had only 47% of the tolerance of 16 to 35 year olds compared to only

28% for those aged 65 years and above. PADMANABAN (2001) argued that belted older drivers were 40 times more likely to sustain a chest fracture in a crash than younger drivers while AUGENSTEIN (2001) also argued that older occupants were more likely to suffer a serious internal chest injury and have a higher rate of complication.

Older Driver Safety Intervention

In the light of all this evidence, it is clear that we need to be considering now what can be done to minimise this impending road safety problem involving older people. OECD (2001) lists a number of areas that have potential for addressing older driver safety, including improved infrastructure, licensing, better land use and education, publicity and training. Of particular interest, here though is what are the opportunities for reductions in fatalities and serious injuries through crash avoidance strategies and technology and improved crashworthiness.

Crashworthiness Options

Vehicle Age

Vehicle crashworthiness in Australia was seen to have doubled between 1970 and 1995 as shown in figure 7 by NEWSTEAD, CAMERON and LE (1997). For crashes that occurred during the early 1990s, they showed that the probability of a driver sustaining a severe injury in a crash fell from 5% to a little over 2% for different aged vehicles. They attributed this to the introduction of design regulations during the early 1970s and further improvements more recently from the introduction of consumer tests and greater consumer awareness of safety, forcing manufacturers to improve the crashworthiness performance. This has been achieved through better management of impact energy and safety technology in recent models.

One option, therefore to improve older drivers' and passengers' safety in a crash is to ensure they are in a superior crashworthy vehicle. From these figures, it is apparent that a more recent car (with improved safety technology such as airbags and better safety belt systems) offers increased potential for them to avoid severe injuries in a crash.

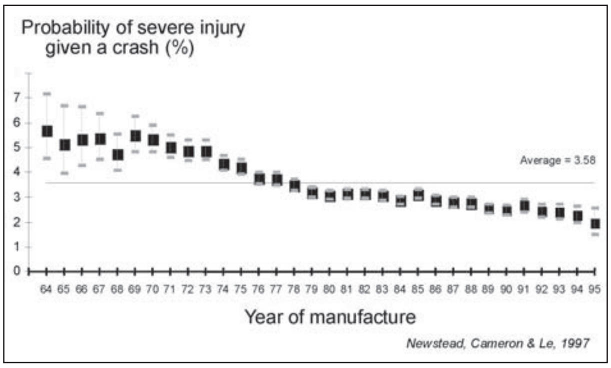

Fig. 7: Vehicle Crashworthiness by age of the vehicle, 1964 to 1995, Australia

Vehicle Mass

Newtonian physics dictates that impact force in a crash is a function of a vehicles' travel speed (squared), its mass and the mass of other vehicles it strikes. Occupants in a vehicle with a mass of 800kgm that hits another head-on at the same travel speed but with a mass of 1600kgm will experience twice the impact force than those in the heavier vehicle, all things being equal. While safety technology will help to improve the vehicle's crashworthiness, there is no getting away from the benefits of increased vehicle mass in a crash.

Another solution, therefore, to improve the risk of serious injury in a crash for older people is to travel in the heaviest vehicle they can handle and afford. Obviously, this has other implications in terms of environmental effects, price, ease of driving and difficulties in manoeuvring and parking that one needs to consider also. Nevertheless, there is no escaping the mass effect when involved in a crash (EVANS, 1991).

Safety Technology

Perhaps the greatest safety improvement in crashworthiness came with the introduction of seat-belts in cars during the 1970s. Countries such as Sweden and Australia were the first to embrace this technology and occupants have reapt the rewards ever since. Seat-belt wearing rates over 90% are commonplace in many parts of Europe and Australia today. EVANS (1991) argued that a lap/shoulder belt reduces the risk of serious injury to a driver in a crash by 41% and 46% in conjunction with a driver airbag. Even greater benefits would result from ensuring the seat-belt is aligned properly with the occupant's shoulder and hips to ensure maximum load carrying capacity and is fitted with a seat-belt retractor.

Fig. 8: Properly fitting seat-belt

Fig. 9: Seat-belt pre-tensioner

Crash Phase	ITS Technology
Pre-crash phase	Speed alerting and active limiting systems
	Adaptive cruise controls
	Vision enhancement
	Forward collision warning and avoidance systems
	Rear collision warning and avoidance systems
	Lane change warning and avoidance systems
	Lane departure warning systems
	Driver vigilance monitoring systems
Crash phase	Seat-belt reminder systems
	Intelligent restraint systems
	Airbags and head protection devices
Post-crash phase	Emergency mayday systems
Exposure reduction	Route navigation systems
	Electronic driving licenses
	Alcohol detection and interlock systems

Tab. 1: Technologies available or near release to avoid crashes and injuries (REGAN et al., 2001)

Even when properly fitted, the seat-belt does cause injury to frail bodies where sternum and rib fractures often occur in older occupants from the seat-belt in a crash and these have been shown to result in life-threatening injury (WANG, cited in ALONZO-ZALDIVAR, 2000). One way of decreasing the belt load has been through the fitment of airbags. (FILDES, DEERY and VULCAN, 1997) demonstrated a 17% reduction in all chest injuries and more than 100% reduction for severe chest injures for drivers of cars fitted with airbags over those without.

The supplementary airbag itself has also been shown to provide good benefits for drivers of cars in a crash from studies in Europe and Australia (FILDES et al., 1996; HUERE et al., 2001; ROSELT et al., 2002). Benefits in reduced harm of 60% were reported among drivers by MORRIS et al. (2001) for airbag fitted vehicles while KIRK et al. (2002) reported 33% reductions in AIS 3+ injuries among belted occupants in airbag-deployed vehicles in frontal crashes.

Crash Aavoidance

Advanced technology to assist drivers avoid crashes has rapidly developed over the last 10 years or so. This technology has focused on information displays, communication, sensing and control devices to assist the driver in adverse driving situations. In addition, systems to alert rescue services are currently being trialed in the USA and Australia to ensure rapid transport to hospital in life-threatening situations. REGAN et al. (2001) outlined a number of options for ITS in-vehicle technologies aimed at crash avoidance as shown in table 1. A number of the more promising systems for improving older driver performance are discussed in more detail below.

ITS Technologies Potential Useful for Older Drivers

Intelligent Speed Adaptation

These devices are aimed at preventing or minimising excursions in travel speed above the posted speed limit. They range from installations that apply positive pressure to the accelerator pedal when travel speed exceeds the posted limit to active interventions (interlocks) that prevent the vehicle travelling above a threshold tolerance. They can involve sophisticated active monitoring of the speed limit through a Global Positioning System

(GPS) to a simpler absolute upper threshold on travel speed. There have been one or two examples of GPS type systems trialed in Europe.

- The ISA Tillburg trial in The Netherlands during 2000 (Ministerie van Verkeer en Waterstaat, 1999) sought to examine whether intelligent speed adaptation is an applicable option as an instrument for speed control. A GPS system was used for monitoring vehicle speed and speed limit deviations were controlled using 3-response variants – advice only, positive throttle pressure, and active intervention through the fuel system. The trial was due to run until October 2000. Because of the limited number of people tested (120 drivers) it was not possible to assess crash savings. However, initial acceptance of 55% among those surveyed rose to 69% after the test and as high as 80% when exposed to additional information (BUSSTRA, 2001).
- The Vision Zero demonstration trials in Sweden had several vehicles fitted out with GPS and positive throttle pressure systems to demonstrate how such a system might work. The cars were donated by SAAB and used to illustrate to their drivers the way in which an interactive speed adaptation system could work and the benefits for the community in such a system. To the authors' knowledge, this system was never formally evaluated in terms of process or outcome, although anecdotally there have been a number of very positive responses by those who drove the on-road course near Trollhätten. In particular, the fact that vehicle speed could not exceed the speed limit without active intervention was observed to have positive benefits by some in not needing to monitor the vehicle speedometer so much and hence keeping the driver's eye on the road ahead much longer.

Fig. 10: Forward Collision Warning

While these systems offer some promise in reducing travel speed and hence crash involvement (and minimising injury outcome), it is understood that no manufacturer has actually introduced such a system in their vehicles, even though the GPS technology is available. It is likely that the introduction of intelligent speed adaptative systems will need to be regulated if they are to become mandatory features in cars of the future.

Forward Collision Warning

These systems are designed to detect an imminent danger of collision ahead and to either warn the driver accordingly or intervene to correct the situation where possible, as shown in figure 10. The Delphi Automotive System FOREWARN and the Eaton Vorad EVT-300 system are examples of FCW systems currently available on the market. They use microwave and Doppler radar sensors to assess an imminent threat and issue visual (and audible) warnings to the driver. REGAN et al. (2001) reported that Jaguar first offered the FOREWARN system on its XKR luxury model in 1999, however, it is not known if the system is now offered on any other models or brands and whether it has been evaluated using data collected in the field, especially for older drivers.

Emergency Maday Systems

Figure 11 shows an example of an emergency mayday early notification system. The system is designed to identify if a crash has occurred in the

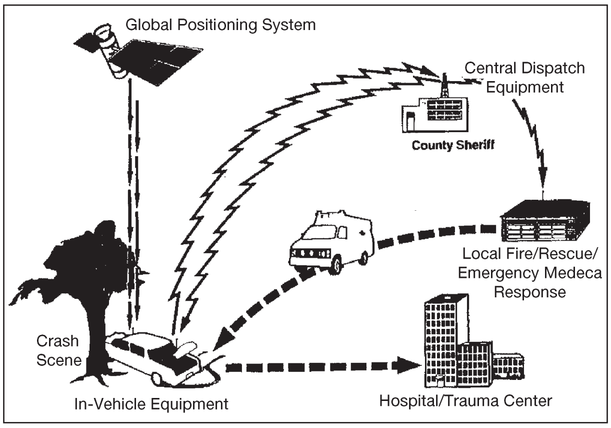

Fig. 11: Emergency mayday system

target vehicle, the location of the crash and whether anyone was seriously injured (via a telephone call to an in-build mobile phone). Data would also be collected on pre-crash information (travel speed, brake status and throttle opening) and crash data (peak crash pulse, seat-belt status and airbag deployment) and transmitted to a central monitoring station. When warranted, emergency services would be initiated and a appropriate destination hospital or trauma centre would be notified.

CHAMPION et al. (1998) argued that an Automatic Notification System (ACN) would have a major influence on reducing EMS response times as well as provide a mechanism whereby treating hospitals could get early notification during transport of an injured patient and hence provide more accurate matching of available local resources with patient needs. They noted three systems in operation in the USA; the RESCU system onboard at least luxury Ford vehicles, the GM ONSTAR system fitted to GM luxury models and the NHTSA/Calspan technology system in Buffalo, under evaluation by the Erie County Medical Center.

DIGGES (2001) described an algorithm (URGENCY) for converting data from onboard crash recorders to assist in identifying crashes that are most likely to have time-critical injuries. The algorithm involved a prediction of the probability of severe injury based on impact severity, car curb weight, airbag and seat-belt deployment, occupant age and sex. Of particular relevance to this paper, he noted an inverse relationship between age and injury risk for equivalent crash severity as shown in figure 12. The algorithm is currently under evaluation but they claim that it, in conjunction with an ACN system had the potential to reduce crashes by around 25%, a figure close to that reported by BRODSKY (1983) who predicted a likely 20% reduction in highway crash injuries generally with better EMS and up to 38% in some rural locations. He claimed that with automatic life saving technologies fully deployed, this would amount to approximately 10,000 deaths saved each year (27 deaths each day) in the USA.

Vision Enhancement

figure 13 shows an enhanced visual image system where night-time views of the road ahead are enhanced through infrared technology and displayed onto the windscreen to provide drivers with advanced warning of hazards ahead. It is considered to be especially beneficial for nighttime driving and in adverse weather conditions. We are aware that the up-market Mercedes Benz, Jaguar and Cadillac vehicles offer commercially available visual enhancement systems and that this is generally presented to the driver in a head-up display projected onto the windscreen of the vehicle. Little information is known about their likely effectiveness and the disbenefits of head-up-displays have also been alluded to by some authors (eg; WARD & PARKS, 1994; BOSSI et al., 1997). GONDAK (1996) claimed that as much as 43 percent of all crashes (and 31 percent of fatal crashes) occurred during inclement and night-time visual conditions and it would be expected that crashes at these times is where the safety benefits from enhanced visual image systems would come from.

Fatigue Monitoring

Older drivers are more likely to tire more quickly than their younger counterparts hence monitoring their level of fatigue and intervening has potential

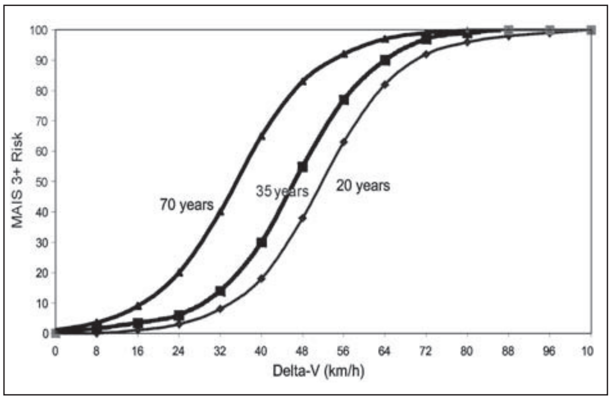

Fig. 12: Risk of MAIS 3+ by impact severity and driver age (DIGGES, 2001)

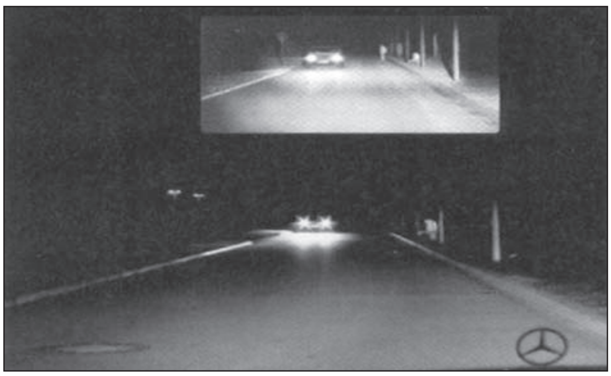

Fig. 13: Enhanced visual image system

road safety benefits. Fatigue monitors have the added bonus of also detecting other performance impairments, such as drink-driving and drug abuse. Drowsiness can be detected by systems that analyse behaviour including rapid acceleration (and deceleration) erratic braking and gear changing, excessive lane changes and inappropriate headway (REGAN et al., 2001).

A few fatigue-monitoring systems are presently available. REGAN et al,. (2001) note that Mack Trucks in the USA employ a system called 'Safetrac' which monitors lane deviations and driver vigilance, while Toyota's and Mitsubishi's 'Advanced Safety Vehicles' incorporate a drowsiness warning system, monitoring performance through driver behaviour and steering control. HARTLEY et al. (2000) argued that the main problems with these systems are their effectiveness and their reliability. Nevertheless, LIND (1997, cited in RUMAR et al., 1999) estimated that with high implementation among vehicle fleets, a driver monitoring system could reduce injury crashes by 20 percent, in particular, among single-vehicle accidents.

Lane Departure Warning

The final crash avoidance system to be considered for improving older driver safety is in providing warnings of lane departures. Older people generally experience difficulty with complex manoeuvres on the road and have restricted head movements. Consequently, they tend to wander more on roads and lane excursions are more likely.

It is hypothesised that lane departure warnings (and improved mirror systems) would be of benefit to older drivers in ensuring they stay within their travel lane. However, lane departure warning systems that are commercially available tend to be relatively immature and unreliable (REGAN et al., 2001) and there is none that we are aware of that is fitted to current model vehicles. Hence, their effectiveness is unknown. REGAN et al. (2001) claimed that they would likely be effective for rural single-vehicle crashes and sideswipes with only a relatively small 5% reduction on all crashes.

Benefits of Technologies for Older Drivers

The likely estimated benefits from these technologies were reported by REGAN and his colleagues from various publications and estimates and are summarised in table 2 below.

These benefits are for all drivers of all ages and it's not sure how effective (or acceptable) they are likely to be among older people. One of the consequences of ageing is a reduced cognitive capacity as the number of brain cells diminishes and an increase in mental disorders such as dementia and Alzheimer and Parkinson diseases occurs. Consequently, they find it difficult to multi-

System	Description	Crash Scenarios	Estimated Benefit
Intelligent speed monitor	Limit speed to posted speed limit	Single-vehicle, head-on, same direction, intersection and pedestrian crashes	20% effectiveness 10.8% reduction
Forward Collision Warn.	Warns of imminent collision danger	All rear-end and same direction crashes	7% reduction
Lane Departure Warning	Warns when deviating from travel lane	Rural single-vehicle, off-path and side swipes	50% effectiveness 5.2% reduction
Fatigue Monitor	Detects impairment due to fatigue, etc.	Single-vehicle crashes	50% effectiveness 4.3% reduction
Mayday system	Automatic notification of crash involvement	All crash types	0% reduction crashes (BRODSKY, 1983) 20% to 38% injury savings
Electronic drivers licence	Prevents unlicensed driving and adjust vehicle	All crashes involving unlicensed drivers	Unknown effectiveness (97.6% expected reduction of unlicensed)
Vision enhancement	Provides an enhanced vision of danger ahead	Single-vehicle, head-on, same direction, intersection and pedestrian crashes	Unknown effectiveness (43% of crashes occur in inclement or night-time visual conditions)

Tab. 2: Summary of the benefits of ITS technologies (REGAN et al., 2001)

task and are easily distracted and confused by competing sources of information. Their vision and hearing also deteriorate and they tend to be less technically skilled.

It is fair then to question their likely effectiveness for older drivers. As part of the European DRIVE II EDDIT project, OXLEY (1996) exposed older drivers to six ITS technologies, generally considered most likely to be beneficial for older drivers. The found that visual enhancement and mayday systems were likely to improve older driver mobility and safety but that collision warning systems and reversing aides would have little impact on improving older driver mobility and safety. He further noted that older drivers preferred auditory instructions in addition to visual displays for both route navigation and rear collision warning systems.

Intersections and complex turning manoeuvres feature predominantly among older driver crashes (FILDES et al., 1994; OXLEY, 2000; ANDREA et al., 2001). They noted that making judgements about when it is safety, to cross in front of turning traffic is difficult for older drivers and pedestrians alike as the ability to judged safe gaps deteriorate with age. While poor vision plays a role in this, so too does their primary reliance on distance away without due consideration about approaching speed. Technology to aid this decision would seem to be paramount to enhance older driver safety. A simple exposure-reduction solution for addressing this was proposed by SPARKE (2002) when he argued for pre-route planning to maximise left-hand turns[1] over right-hand ones for journeys in busy urban areas.

Human Factors Research

While many of the technologies reported here do offer promise for reducing older driver crashes, it is clear that they need to be evaluated on road or road-like driving environments. This is particularly the case as many of these ITS devices have not been developed or tested for vulnerable road users (REGAN et al., 2001). This is an area of urgent research for the future to ensure that the current avalanche of new safety technology is optimal for the road users it is supposedly targeted to be of benefit for. This research needs to encompass analytical studies focussing on the most effective human-machine interface and examining the behavioural consequences of such technologies, separately as well as in conjunction with each other. In particular, the research needs to examine the consequences of technology for differing age and sex groups as well as other vulnerable members of society who are regular road users. Without such research, we are likely to be overrun with a smorgasbord of new safety developments that may well have unforseen safety disbenefits.

Conclusions

This paper examined the injury implications for older drivers in crashes and trends in ageing of western societies. The need for improvements in older driver safety is plainly evident from this analysis. A number of safety technologies were identified and discussed which have potential for improving vehicle older driver crash avoidance and crashworthiness. While there were some promising estimates available of the likely benefits of this technology for improving safety, it is evident that they need to be confirmed for older drivers, given their age-related disabilities and sensory limitations. Further research is urgently required to ensure that these technologies yield safety benefits without any disbenefits for older drivers.

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[1] Cars in Australia drive on the left-hand side of the road, hence turning across a traffic stream involves a right-hand turn manoeuvre.

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