A review of the literature on older driver risk, and an analysis of older drivers' collisions in Suffolk 2005-2007

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The Problem of Older Drivers' Road Safety:

A literature review

1. Introduction

There has long been concern for the 'problem' of older drivers' road safety in terms of their risk to others and to themselves. This particular driver group is widely viewed as vulnerable to higher road accident involvement liability. A wealth of research has examined various aspects of this problem including type of accident, causal and contributing factors, evaluation and intervention techniques, etc. Different quarters offer alternative arguments – and some even question the validity of the 'problem' itself. This document provides a review of the relevant literature and various aspects of the 'older driver problem' that have been studied, as a broad assessment and an overall summary of the current situation for this particular driver population.

This literature review begins with a brief background to the subject, defining the subject and research focus. It then provides an examination of statistical evidence that supports the existence of a potential problem, gathered both globally and specifically in the UK. It then goes on to explore what appear to be the most significant causal factors in this problem – the physiological, behavioural, social and environmental conditions that seem to lead to difficulties for older drivers. The review then looks at the nature of mitigating factors and the efficacy of various evaluation and intervention approaches that have been applied to the older driver problem. Finally, the review concludes with an overall summary of all of the previous work along with its implications for future work and recommendations for interventions in the current climate.

2. Background

2.1 What is the 'older driver'?

Firstly, it is important to establish what we mean by 'older drivers'. Different definitions exist and have been used for various research purposes. Age range parameters used to distinguish 'older drivers' have been classified sometimes with specific contextual purpose but most often have been set arbitrarily. The UK Royal Society for the Prevention of Accidents (ROSPA) states that *"…older drivers are defined as drivers over the age of 60 years. However, it is acknowledged that older drivers do not form an homogenous group and wide variations in their characteristics and driving abilities exist within this general category"*[1].

To establish an overall picture of the current situation and understanding of older drivers this literature review has examined a wide range of information sources that use different 'older' parameters and definitions. We assume the

[1] http://www.rospa.com/roadsafety/advice/driving/older_drivers.htm

ROSPA definition is apt but also that the various parameters that have been used are potentially relevant to the debate in general. Thus, for the purposes of this report we refer to 'older' drivers in a general sense, as those of 60^{+} years and will specify where any particular thresholds and ranges are important to the debate or an issue in general.

2.2 What is the 'older driver problem'?

Older drivers, who have been found over-represented in accident involvement statistics, are also the fastest growing driver population [52]. We know that there are a range of aging-related physiological changes that may negatively affect driving ability, namely declines in vision, hearing, reaction time and the musculoskeletal system [63]. Additionally, we know that age-onset medical conditions and associated medications often play a part in their accident involvement [81, 82]. We also know from police reports and insurance data that older drivers are more likely to be considered responsible for the accidents in which they are involved [111]. The other salient problem is that older individuals tend to suffer more serious injury and more frequent risk of fatality as a result of an accident, in the region of 2-5 times more than that of a younger person, because of their increased physical frailty [34].

2.2.1 Rising older driver population

Continuing advances in health / medicine means people are generally living longer and one consequence is that the older driver population will increase simply in line with general population increase. Additionally, people are more dependent on driving; car driving has become the preferred mode of transport for all age groups, older drivers have particular social and emotional needs that make them prefer to continue driving their own cars [76]. As communities have become more dispersed and regional infrastructures have increasingly made transport use an imperative, older drivers are becoming increasingly reliant on driving to compensate for physical frailties and disabilities that impede their mobility [77, 78]. Consequently, the older driver population is rapidly expanding. A corollary of this is that, due to longer life expectancies and more equitable lifestyles, the elderly female driver group is an especially increasing sector of the growing older driver population.

2.2.2 Increased decline in performance

We know that as people get older they are vulnerable to the onset of various impairments. A wealth of research has addressed the wide range of potential age-related declines which may lead to greater accident risk the older driving population. The physiological functions (visual, cognitive, perceptual etc.) that may deteriorate and contribute to increased risk of accident involvement are discussed in more detail in section 4.1.

2.2.3 Higher accident liability

With significant increases in the number of older car drivers, along with parallel increases in this group's need for travel (exposure), it is clear that any particular issues and problems that may be pertinent to this driver group will also be on the increase. However, as is so often the case, debates with

opposing perspectives mean that identification of these issues and problems is being delayed. On the one hand evidence suggests that older drivers represent a particularly vulnerable group with high relative accident and fatality rates and a propensity to sustain more serious injury to themselves in crashes. On the other hand, evidence also suggests that actually this driver group is relatively safe compared to younger driver groups and that enabling unimpaired seniors to drive for longer may have a positive impact on traffic safety. It seems this dichotomy is due to the way in which accident research has so often been confounded by the 'low mileage bias' (LMB) where greater mileage drivers are less prone to accidents *per mile* than those who drive less [108, 127, 129].

For example, if we just look at the proportion of crashes experienced by the entire licenced driver population then the older groups appear to be the safest, with the least number of crashes. However, this doesn't take into account the differences between the groups in terms of exposure, where the younger driver tends to experience much higher mileage per annum than their seniors. So, when crash rates per miles travelled are calculated instead we find that older age groups are far more vulnerable to crash risk and this is incremental as a function of increasing age to the point where the 85^{+} driver has about the same risk as that of a driver in the 20-24 year old age group [47]. Dulisse suggests that the risk posed by the 65-74 is no greater than that of younger drivers and that in the 75 age group the higher risk is actually "very small" and only due to the methodological misgivings of previous work [40].

2.2.4 Greater injury severity

Another critical factor to consider as an older driver problem is how the severity of outcome following a crash differs between age groups where it is clear that older drivers have a much higher likelihood of fatality. Again, this vulnerability rises along with age increments such that the 85^{+} age group are over-represented in serious injury and fatality outcomes [48]. It seems that the higher rates of older drivers' injury and outcome severity are likely to be due in some way to the nature of the type of accidents to which they seem more vulnerable.

Due to the rising numbers of older drivers it is predicted that: *"…although the numbers of accidents per unit distance travelled may stay the same over the next 30 years, the absolute numbers of fatal accidents involving elderly drivers are set to increase"* [34, p.5]. Consequently, we need to examine all of the various issues and arguments regarding why the older driver population is perhaps simultaneously the safest and the most at-risk group to most effectively and efficiently plan for and accommodate the rising number of elderly drivers on our roads to reduce the higher involvement of our elderly population in accidents. We therefore consider the 'potential problem' of the older driver.

3. Evidence and perspectives

The potential problem of having a rapidly expanding older driver population will undoubtedly vary across the globe according to national / regional /

cultural differences. For example, as we know that road traffic injuries are more prevalent as a function of levels of motorisation, the more industrialised countries become the more road traffic safety issue is going to be of greater concern [91]. In order to provide a general overview of the older driver situation this section will examine data and perspectives from various research sources and safety organisations. It begins with a summary of the general global perspective, in particular information from the World Health Organisation and the plethora of US research; it then discusses implications for the UK older driver sector situation.

3.1 Epidemiology

It has been predicted that road traffic accidents will be the sixth most prevalent cause of global deaths by the year 2020 [38]. It is also predicted that as older populations are expanding globally; the Organisation for Economic and Co-operation Development (OECD) forecast that by 2050 one quarter of their member nations will be over 65 years old plus [43], and the World Health Organisation (WHO) expect by the year 2030 over 20% of the individual populations in higher income countries will be aged 65 years and over [36]. Due to the increasing proportion of older people in society and their greater propensity to continue driving, older drivers represent the fastest growing driver group in our population [24, 25, 26]. As a result of these developments, it is almost inevitable that the crash frequency of older drivers will increase dramatically.

Within this expansion of the older driver population, there are other demographic changes. Not only are older drivers continuing to drive into later years but there is increasingly less gender difference such that females have become more prevalent in the older driver population and this trend is expected to continue to rise [34]. The factors that influence risk differs between the male and female populations; whilst risk factors are more numerous for the male elderly driver evidence indicates that women who live alone and those with back pain are at more risk [104]. Passenger injuries as a result of a crash are more likely with female drivers [105]. Moreover, evidence indicates that women are more prone to be involved in crashes that occur in 'safest' conditions, i.e. daylight, low volume traffic, good weather etc [42]. Older drivers' traffic accidents in general are more likely to involve multiple vehicles and more serious injuries [34].

3.2 World Health Organisation

The World Health Organisation (WHO) has taken a leading role in raising awareness of the global problem of road safety and the significant continuous rise in injuries and fatalities as a consequence of progressive motorisation. To this end, the WHO produced an influential and wide-reaching report – the *'World Report on Road Traffic Injury Prevention'* in 2004. Due to the universal impact of the report the key components relative to the older driver population are now summarised.

In this report the WHO stipulate that the four elements of road traffic risk are: exposure, probability of a crash, probability of injury, and injury outcome (factors affecting ability to treat / withstand) [36]. Their influential and wide-reaching *'World Report on Road Traffic Injury Prevention'* of 2004 states that road safety is only the *"secondary issue"* from a public health perspective of the older population, after the restriction of mobility out of doors due to transport system failures. The report provides little reference to the specific issues surrounding older people as drivers – not only because elderly pedestrians are of greater concern but also it seems because this driver group is not considered as much of a problem as the young and novice driver group.

Indeed, the only specific reference to the global older driver population seems to assume that there is no problem due to natural rates of voluntary cessation and that the primary concern is for older pedestrian road users:

> *Despite the rising number of older people holding driving licences in such [high-income] countries, their declining driving ability as well as possible financial constraints will mean that many of them will have to give up driving. In many low-income countries, older people may never have driven in the first place. Worldwide, a large proportion of older people will still be dependent on public transport or will walk.*
>
> WHO, 2004, p74

The report recognises that older people may rely on their private cars more than younger groups for mobility but emphasises the types of crashes to which they are more vulnerable, such as at intersections and other complex traffic situations, are generally not through lack of caution like those of the younger driver, e.g. speeding, careless overtaking, etc. Although it admits that older people are often overrepresented in traffic fatalities relative to their proportion of the overall population the WHO report discusses a *"widespread misconception"* about older drivers' danger. Focusing on the fourth element of road traffic risk – injury outcome – the report attributes statistically higher injury and fatality rates mainly "*to the increased physical frailty of the elderly"* (p.47). It therefore does not support calls from other quarters for increased age-related screening and licence withdrawal policy.

> *"While it is accepted that certain groups of older drivers should not drive – such as those suffering from advanced forms of dementia – mandatory screening of drivers based on age is not recommended. Improvements in pedestrian infrastructure, and interventions to support safe driving as long as possible for older people, are generally regarded as better investments for their safety and mobility than attempts to stop them from driving.*
>
> WHO, 2004, p47

3.3 United States.

In the United States in 2006 older individuals represented 14 percent of all traffic fatalities and 14 percent of all vehicle occupant fatalities [82]. Most of the research interest in the potential problem of a wider older driver population

appears to have emanated from the United States and has led to the publication of a range of statistical data that may be useful as an indication of the general situation across other Western / similarly motorised nations. At a national level, U.S. data regarding various older driver issues that together provides a good general insight from which we can evaluate the current problems and predict those of the future in other countries such as here in the U.K.

In respect of projected growth, the U.S. Department of Health and Human Services agency, the Administration on Aging (AoA) predicts that the 65^{+} age group will double over the next 30 years and will make up one fifth of the entire population by 2030 – along with an increasing dependency on driving for personal transportation needs, as described. In terms of older driver safety, the AoA also explains that the reason why this section of the population seem to be the *most* safe but also *least* safe group of drivers difference is simply due to how safety is conceptualised and measured (LMB).

Like studies in most countries, U.S. research has shown that older people's crashes are more likely to occur at *intersections*, particularly when making *turns* along with driving situations including *U turns, reversing, parking, leaving parking positions and on-road starting off / pulling away* [46]. The greater severity of outcome for this driver group is undoubtedly to some extent due to the high number of side impacts and angle collisions involved in their crashes (130). The data presented shows, therefore, that the higher risk of having a crash coupled with the higher outcome severity risk supports that there *is* an older driver problem, and it is based on aspects of risk. Older driver age groups unfortunately represent a particularly vulnerable sector of the general driving public and are significantly more at risk of a) crash avoidance and b) crash survivability.

3.4 United Kingdom

It is estimated that by the year 2031 almost 30% of the U.K. population will be over 60 [32]. Within this time frame it has also been estimated that by the year 2015 some four and a half million people aged over 70 will hold a current driving licence in the U.K. [33]. Voluntary cessation patterns follow those of other countries in that drivers who continue into later years tend to be male and with no cognitive impairments, and the decisions appear to be based on self-assessment and acceptance of failing abilities and not by physicians' assessments [96].

The gender difference of previous U.K. older driver generations (which has been far more noticeable than in other Western nations) is also set to change significantly, as the female older driver sector is the most rapidly growing section of the driving population, in line with other countries. The Driver and Vehicle Licensing Agency (DVLA) has estimated that whereas amongst 80-89 year olds in 1993 44% of men and 11% of women held a current driving licence, by 2020 the figures for this age group will rise to around 65% and 35% respectively [34]. It is clear then that any issues pertinent to female elderly driver groups should be considered and planned for appropriately within this country.

Other UK trends mirror those found general in research. Accident involvement and number of injuries per miles driven is highest among the very youngest and oldest driver groups [15, 19] and older drivers are more vulnerable because in a crash they tend to be more likely to sustain more critical and fatal injuries [46, 47]. Older drivers, incrementally with age, tend to be involved in comparatively more crashes resulting in fatalities and hospital admissions than younger driver age groups, although the actual number of such crashes is relatively small when differences in exposure levels are taken into account [13, 30]. This LMB problem, set out in section 2.2 explains how older, lower mileage drivers actually have no increased risk per distance driven [108] has now been widely recognised in more recent studies: *"the previous perception of an age-related risk increase of accidents per distance driven arises from a failure to control for low mileage bias at all ages"* [17, p.271].

4. Causal factors

4.1 Physiological Decrements

Research has shown that older drivers in the 70+ years age group tend to not be able to perform as well as younger people on driving skills and manoeuvres such as speed control, tracking, positioning and reversing [83, 84]. This is probably largely due to the fact that, as people age, they tend to have a range of deteriorating physiological functions– visual, cognitive, and perceptual – that contribute to increase risk of accident involvement [27, 28, 29, 30] and to voluntary and involuntary driving cessation [96]. Some of these key functions are now summarised.

4.1.1 Visual

As approximately 90% of information processed in the driving task is visual the potential effects on driver performance of age-related visual impairment is an obvious potential problem for older drivers [123]. Generally, it is assumed that older drivers will naturally have visual impairment as a consequence of their age [27]. The older driver population will have an increased prevalence of various visual degenerative disorders such as cataracts, glaucoma, diabetic retinopathy, macular and other retinal degenerations, etc., along with proneness to decrements to visual acuity and visual fields, contrast sensitivity, etc.

The problem is, it seems, that along with the reluctance for older people to cease driving when they reach a stage at which it is becoming unsafe it is also the case that individuals are not aware of the extent to which their failing visual abilities are a hindrance and risk factor [63]. For example, drivers in of 70^{+} have been found to not be aware of the extent to which their visual acuity has become a problem, especially in poor light, and many do not appropriately wear prescription spectacles [63]. However, it also appears that this particular potential problem of the older driver is under debate, as it seems that measurements of visual decrements *"are not, by themselves, a good representation of the complex visual skills needed in the driving task"* [34, p.10].

Age-related visual impairments have been found to have significant deleterious effects on sign detection and recognition of signs and hazards, ability and associated time needed to complete driving tasks and manoeuvring, and reaction times [10, 11, 66]. Some suspected problems, such as the effect of colour blindness on sign recognition in the UK given our colour-based system [34], currently lack research evidence. However, research conducted amongst drivers with no recognised visual impairment found no significant difference between age groups [9] implying that we cannot assume age-related hazards due to visual impairments *per se*.

Research with people who have clinically diagnosed visual impairments due to eye disease has found that people in this group tend not to accurately gauge the impact of their impairment and their subsequent degraded driving performance [6]. There is a lot of evidence indicating that older drivers often adapt their driving to compensate for visual impairments such as by driving slower or avoiding lane-changes [8]. However, accident analysis has made associations between people with eye disease visual impairments and road accident rates, although thus far the link is somewhat confused by the potential interfering effects of medication [7]. There can also be significant differences between self-reports and formal accident reports with respect to vision impairment (acuity, contrast sensitivity, peripheral visual field sensitivity, useful field of view) [12].

Visual Field

Although much of the research that has been reviewed has not produced consistent and conclusive findings we know that loss of visual field – defined as "*the extent of visual space over which vision is possible with the eyes held in a fixed position"* [68, p.499] is most severe in the 65^{+} age group, with significant increases in crash rates compared to normally sighted people [69, 70]. More recently, research has focused on the 'useful field of view' (UFOV), a pre-attentive measure defined as *"the total visual field area from which target characteristics can be acquired when eye and head movements are precluded"* [71, p.37]. Most research in this area has found age-related decrements in UFOV [73] and been able to show association with poor driving performance [115] and actual crash frequency [72].

Visual Attention and Acuity (Static and Dynamic)

It has long been identified that both static visual acuity (SVA) and dynamic visual acuity (DVA) deteriorates significantly with age [65]. As a result, the potential impact that this has on the driving task has long been of concern [64]. However, whilst the negative effects of minimally reduced SVA seems to have a limited impact on the risk of injury collisions for older drivers [67] and the research has proved inconclusive, there is stronger evidence supporting the importance of DVA for screening to predict hazards and collisions:

> *"Dynamic visual acuity (DVA) is the ability to resolve the details of an object while there is relative motion between the target and*

> *the observer. It is potentially the most informative measure of visual acuity"*
>
> Banks, Moore, Liu and Wu, 2004 [64]

It appears that visual attention and search efficiency appears to decline with age in respect of 'bottom-up' processing which simply relies on searching for salient differences in display features (as opposed to top-down which requires an individual to have knowledge of features and how they differ) [50].

Most importantly perhaps, certainly for road engineers and designers, is the influence of illumination and the potential hazards of poor light for the visually impaired. It has been found that for every decade after the age of 25, drivers may need twice the brightness at night to receive visual information, such that by age the age of 75 some drivers may need 32 times the brightness that they did when they were aged 25 [34]. In regard to night time legibility of road signs, older people may need to be 23-35% closer to the signs to accurately interpret the orientation [92, 93].

> *The 1988 study by the AA Foundation for Road Safety found that, amongst older drivers, the most commonly reported difficulty in night driving was seeing the road, followed by dazzle or glare. Possible road improvements mentioned by them were reflective edge lining, especially on unlit roads, and more street lighting, especially at junctions.*
>
> [34, p.12]

Glare

Age often leads to decrements in *contrast sensitivity* – the visual ability to see objects that may not be outlined clearly or that do not stand out from their background. Loss of contrast sensitivity, which can be due to acute causes like cataracts or simply from typical ageing of the eye's tissues, makes the older (65^{+}) driver more sensitive to glare, more vulnerable to its disabling effects, and less able to recover from it [74, 75]. The Department for Transport (DfT) suggest that this may be a particular problem for situations when an older driver suddenly encounters an approaching vehicle using main beam coming round a blind corner *"leaving little time for visual adaptation before avoidance"* [34, p.13]. The subsequent DfT recommendation is that provision of street lighting would prevent the need for use of main beam near such corners.

It has also been recommended following specific research that road markings are made prominent to assist older drivers deal with the problem of glare, particularly in wet and adverse climatic conditions [94]. It seems that the negative effects of glare on older drivers is worse on perception of horizontal information (road markings) and better for vertical information (roadside signs, etc.); unsurprisingly it has also been found to be worse in road situations involving two-lane roads where there is no distinct separation from oncoming vehicles [94].

4.1.2 Auditory

Although research has not directly associated injury-related crashes with impaired hearing, driving while using hearing aids appears to increase risk to about two times the level of other drivers [67]. It has been proposed that the wearing of hearing aids while driving may result in feedback and distracting reaction noise that contributes to these higher rates of collision [124].

4.1.3 Cognitive

Obviously the visual and hearing functions discussed above are related to, and governed by, cognitive functioning. Age-related impairments to cognitive functioning have long been a primary focus of concern as 'informational' causes have been attributed as the cause of the majority of accidents [97, 98, 99]. In a study examining older drivers it was found that amongst those who had licence suspensions because of their crash-involvement there was a pattern of cognitive deficits related to visual, perceptual and motor functioning [128].

As people get older they tend to prioritise accuracy above speed when performing tasks and find it more difficult to ignore irrelevant or peripheral information; thus, they prefer to take stock of all available information to make sure they have accounted for every detail rather than get the task performed as quickly as it could be [86, 87]. It has also been found that stressful, cognitively demanding situations seem to exacerbate performance decrements more in older people [88, 89]. Thus, this could to some extent explain the lack of confidence that older drivers experience when approaching complex intersections and traffic conditions, which will be discussed below in section 4.2.1.

Dementia

Dementia is a progressive decline in various aspects of cognitive functioning, including memory, attention, language, and problem solving, that is much faster decline than would typically occur due to normal aging. For the majority of sufferers the symptoms cannot be halted or reversed and it is well known that the condition is predominant amongst older people in the population.

Reaction time

It seems that even with frequency of exposure and experience of the driving task, age still depreciates people's reaction or response times [125]. For a sample of U.K. drivers over 70 years a significant relationship between reaction time and serious driving errors and car control has been found [131] indicating the effects of age-related declines. They are also slower at recovering from errors and 'incorrect anticipations' [34].

These physiological factors are not by any means an exhaustive list of all that may affect older people's driving abilities, but they are those most salient in the relevant literature. It is also worth noting that we often generalise when considering age-onset impairments such that even though we know there is more likelihood of physiological decline as age progresses, individual

differences can be overlooked: *"age is not the reliable index of functional impairment that society has customarily taken it to be"* [107].

4.2 Behavioural factors

As discussed in previous sections, there is evidence to suggest that older drivers are reluctant to give up driving and in fact are more reliant on personal cars in current society to remain independently mobile [53, 24]. There is also evidence demonstrating that driving cessation, even via voluntary self-regulation, can lead to a range of negative psychological outcomes such as regret, lower sense of self worth and feelings of social isolation [54, 55]. It seems that even the prospect of giving up driving can lead to considerable depression and depressive feelings [56].

The impact of self perceptions on self-regulation driving decisions is evident [53, 54, 57, 58]. It seems that how people perceive and have confidence in their own abilities is a major impact on safety-related choices and behaviours, particularly in regard to cessation [59, 60, 61]. It appears that the lack of confidence and cautiousness of older drivers is attributed to their need to process only the most relevant information and balance this priority with time, particularly in complex circumstances. It is also the case that more elderly people require more time to process information in order to make decisions. Thus, in tricky road situations, older drivers require more information and more time to process it before selecting a course of action; this is likely to be a key factor in accident causation. It seems that effective on-road decision-making relies on a balance between information processing and speed of reaction [90] and it is this that the older driver finds difficult to do, particularly under pressure.

Studies have established general differences in the driving behaviours of older drivers compared to those of younger age groups. For example, older drivers from around 65 years old have been found to be lack confidence more when approaching junctions, although this means they do tend to slow down earlier and approach more slowly and smoothly. However, this lack of confident approach means that on motorways older drivers are more prone to approaching slowly and meet difficulties merging onto the motorway and into the traffic flow; they tend to enter hesitantly, erratically and consequently sometimes very late and precariously [85].

On country roads, the older individual tends to drive more consistently and smoothly, with fewer accelerations and braking actions, than younger age groups. However, on inner city roads, the older driver apparently makes many more errors, especially: failing to notice traffic lights, disregarding traffic system priorities, and failing to reduce speed adequately at road-level railway crossings [85].

In contrast to the characteristics that make younger driver groups at-risk, the older driver is more likely to be law-abiding and cautious [79]. They are far more likely to comply with seat belt wearing laws [133] and those involved in fatal crashes are least likely to have been under the influence of alcohol consumption [82].

4.3 Environmental factors

4.3.1 Car design and automation

Unsurprisingly, older drivers with onset physical impairments experience difficulties dealing with specific features of the car itself such as turning to look out of the rear window and getting in and out of the car [37]. However, it is not just mobility issues that affect the abilities and comfort of the older driver groups behind the wheel – there are a range of visual display and technological function issues of impact [126].

4.3.2 Mobile phone and communications technologies

Older drivers' risks from mobile phone use when driving is not a significant current problem – unsurprisingly, older people are generally not as reliant on mobile phone and communications technologies in general compared to younger age groups [49]. Additionally, lower mobile phone use at the wheel is also associated with being female, lower mileage, and occupation – all distinct factors related to our current elderly driving age groups [49]

4.3.3 Road engineering

Signage

Research has produced quite conflicting findings about the extent to which older drivers may or may not benefit from and respond to road signs. Some findings indicate that older drivers experience difficulty in sign recognition and understanding [100] or may even be prone to ignoring road signage [101]. However, other findings demonstrate that – in line with the previously discussed law-abiding and conscientious nature – older drivers are more likely to respond in order to comply with traffic regulations [102; cited in 103].

In any case, there is evidence to suggest that drivers' abilities to recognize and comprehend road signs is not associated with at-fault accident involvement – risky (high accident involvement) drivers are as cautious and good at understanding traffic signs as (no accident involvement) drivers in (31, 44).

Intersections and night driving

Much evidence has shown an increased risk for older drivers of multiple-vehicle crash involvement at intersections, particularly for drivers aged 85 and older [14] although one study found that older drivers' fatal accidents at intersections are typically in daylight and at low speeds [132].

Driving in darkness has been found to be another problem for older drivers, particularly related to crash involvement for males in a) multi-vehicle crashes where they are struck in the side or rear by another vehicle, and b) single-vehicle crashes where they run off the road on a straight section [16].

5. Mitigating factors

5.1 Self regulation

Older drivers have been found to self-regulate their risk by adapting their driving behaviour in response to the effects of their age-related vulnerability [57]. For example, they may avoid driving at riskier times and situations such as at night, during rush hour times, during bad weather, more complex types of road, etc [2; 26, 62]. They are also sensitive to, and avoidant of, the hazards imposed by climate and road conditions [80]. Interrelated aspects of driving that older people have report finding most difficult include heavy traffic, junction turns onto the opposite side of the road (left turns in the US system), fatigue, and the high speeds of other drivers on the road [62].

5.2 Cessation

It seems that in light of the various social and emotional needs for the older driver to remain driving and as a result of their greater experience, the older driver becomes more hazard-aware and risk-perceptive which manifests in safer driving behaviours. They also seem to naturally reduce their driving exposure as time goes on [35]. It seems they are often reluctant to relinquish driving activities despite knowing that the driving task is becoming more difficult for them as it can be a difficult and emotive issue to admit [1]. For most older drivers today, driving has been a life-long activity (and often pleasure) and they are therefore reluctant to give it up as this will bring a complete lifestyle change [5]. The ability to possess and drive a car can promote a range of positive emotions such as self esteem, confidence, autonomy and status [23] and so want to remain driving for as long as possible and then have some personal control over how and when they give up this activity [54].

Although older drivers can self-regulate to avoid more dangerous exposure times / situations they may prefer or need to continue to drive during later years where their vulnerability is high or even critical. For the older driver who experiences specific forms of physical impairment, such as post-stroke, the car not only offers continued independence and freedom but can allow greater mobility than forms of public transport [4]. For all of these reasons no doubt, older drivers typically want to withdraw from the activity slowly and gradually rather than in a fast and imposed manner [57]. It seems the differences between people's decisions to give up driving are a function of individual differences in self perceptions [53, 54, 57, 58] regarding ability / decrements and in particular their levels of confidence [59, 60, 61].

In the UK, it seems that driving cessation occurs mainly on a voluntary basis as people elect to retire from driving when they recognise declines in either health (physical and cognitive) and is most common after the ages of 80 years and in the female driver population [96]. However, another significantly reported reason for driving cessation is loss of confidence (and associated psychological reasons) which is, as discussed also likely to be related to recognition of cognitive and physical decline [96]. That health problems and

lack of confidence are found the most common causes of driving cessation supports previous research in the UK and elsewhere [95].

5.3 Legislation and policy

To date, the wide attention that has been paid to the road safety problems of young and novice has not been matched with interest in our older driver fraternity [3] which of course means that any specific problems that may be relevant to them may not be adequately addressed. It could be that the comparative lack of attention paid to older drivers' road safety vulnerabilities compared to that of young and novice driver groups is due to the relatively smaller number of crashes involving older drivers. However it may also be the case that older drivers have not been considered as much of a danger to others (to society) compared to younger driver groups on the basis that evidence has shown that their accident involvements generally cause injuries to self rather than to others [15, 22].

5.3.1 Age-related assessments for re-licensure

There have been numerous calls for increases / implementations of aged-related assessment checks for licence renewal by various authors and agencies – and perhaps a disproportionate focus by the media [39]. Nonetheless, as with the young driver groups, there is no universal approach to age-related licensure in respect of older drivers. Moreover, there are often regional differences even within the same country - for example, in the US and Australia policies and laws vary across different states [106]. In smaller countries, such as within the European union, there may be national consistency but little to align the different union member state nations. Some countries licence people for life whereas others have enforced regular assessment checks for re-licence / withdrawal decisions. In Finland, assessments begin when the driver is just 45 years old. However, there are strong arguments against age-related assessments like this.
Firstly, given the evidence showing that people voluntarily retire from driving when they self-diagnose physical and cognitive declines, is there any need to operate a formal assessment system? UK research suggests that there is no need to screen for impairment as older drivers tend to withdraw when they realise when these occur and might affect the driving task:

> *…the call to screen for dementia or health status in the older population will not reduce the marked rise in accidents seen with age, because those with cognitive impairment and failing health in the oldest age groups have already chosen to stop driving..*
>
> [96, p.707]

Second, in respect of mandatory re-testing schemes that are used in many countries for drivers above a specified 'risk-related' age, research using actual crash involvement rates suggests these "*have no demonstrable road safety benefits overall"* [110, p.326]. A recent statistical cost-benefit analysis also concluded that current licence renewal screening assessments are not helpful because the technology is not yet capable of accurately identifying accident-risk [114].

Age-based assessments of fitness to drive are perhaps simplistic measures that preclude able drivers to remain independently mobile, thereby creating the need for a range of other resources. Instead, it is recommended that fitness to drive is assessed using fairer and more strategic approaches to identify at-risk individuals [45].

5.3.2 Lower mileage bias

Policy makers have previously looked to the wealth of research findings that have indicated the accident liability of older drivers. However, there has been increasing evidence of lower mileage bias (LMB) in earlier analyses and the exaggeration of risk for low mileage drivers that it causes, as described in Section 2.2. So, more recently there have been calls for policy makers to take LMB into account and consider the fairness of rules that preclude older drivers on generalised assumptions of greater risk [109].

6. Interventions

Given that older drivers have problems with specific features of their cars, as discussed above [37] interventions that include own-car assessments and training elements clearly have the potential to assist the older driver to deal with and compensate for the particular problems they have. However, it is essential that facilitators are fully aware of potential difficulties and equipped with evaluative and compensatory strategies that they can use to identify and address such problems with the driver.

Increasing the number of licenced older drivers (>60 years) has been related to significant *negative* effects on crash fatality rates [39]. Whilst these findings may not be completely generalisable to the wider population they do indicate that caution is needed before considering more stringent licensure restrictions.

6.1 Driver education

Although driver education schemes are becoming increasingly popular there is some evidence to suggest that these are not always effective and may result in raising risk because the experienced driver often lacks awareness of the decline of their own driving skills and is resistant to changing beliefs that often entail blaming others for negative on-road events [41].

We have long known that ‘traditional’ approaches to general driver training which focuses on physical handling skills performance outcomes has very limited effects on driver safety improvements, or may even be counter-productive by inflating confidence [120, 121]. Recent research has shown that this is also the case with educational interventions for older drivers [122]. However, with the right focus, tailored driver education can target and adapt people’s individual beliefs such that the positive impact on their driver behaviour and safety is long-term [118]. Accordingly, driver education programmes that are tailored for older people and to target their particular needs can have extremely beneficial effects in improving their knowledge and understanding of safe practices [117]. Education can also be used to

encourage older drivers to evaluate their circumstances and appropriate self-regulation [119].

Education programmes need to ensure design, delivery, evaluation and all other essential elements are the most appropriate for the particular driver group for which they are required. Additionally, however, there is a need to consider the most effective facilitation of these programmes too *"[F]rom an implementation perspective, we should identify the best practices for the delivery… to older adults and ensure that all participants successfully pass all evaluations after…"* [117, p.75]

6.2 In-vehicle data recording

Traditionally, methods of researching and examining driver behaviour and exposure has relied on self-reports and surveys. However, advances in technology now provides the opportunity to monitor drivers via electronic data logging and this technique has been found to not only produce a more comprehensive and objective range of information but appears to be more preferable to older driver participants [116]. Although it may be assumed that older people lack confidence and ability to interact with technology, it has been found that driving simulator assessments can be used to identify higher risk of crash involvement amongst older drivers [112].

7. The future…

Various research studies have demonstrated that in absence of distinct functional impairment the older driver will be as safe as the younger driver [17, 18]. Moreover, research evidence supports that there is an increase in safer driving behaviour and more risk-averse, hazard-aware driving styles as a function of age [19] and points towards this effect being a result of age-related experience which brings a more sensitive and accurate perception of personal risk and limitations [20; 21]. Therefore, this suggests a possible route for future strategies and interventions that address the older driver problem.

Attempts to restrict older drivers by increasing age-based assessment and licence withdrawal enforcements have become more widespread but are opposed. Some view the evidence to support these measures as suspect [110]. Others advocate that age-based restrictions need to be carefully balanced with social needs and the potential for serious detriment being caused to older people's quality of life [52, 53].

As our younger generations grow up and become our elderly driver population it is highly likely they will change the nature of older driver behaviour. For example, despite growing legal and social pressures not to drive when using a mobile phone (hand-held or hands-free) it is likely that future older driver generations who are more familiar and reliant upon these technologies will present a higher usage and therefore a higher risk of this particular problem. Another example of future changes to driver behaviour may be in aggression.

Significant changes found to *self perception of vision and driving*, *attitudes towards driver safety* and *driver behaviour* [119]

Aggressive driving behaviours are not exclusively a younger person's issue but it is the case that in the current climate incidents do not involve the eldest driver age groups. Indeed, it seems that youths are more likely to engage in risky driving behaviours in general due to them being more vulnerable to 'risk behaviour syndrome' to satisfy developmental social needs [50]. This no doubt reflects general socio-cultural characteristics whereby our more senior citizens are more likely to respect mandatory laws aswell as the disciplinary effects of social norms and expectations. However, our future elder driver generations may differ and a general rise in aggressive behaviours and lower respect for social conventions may be reflected in greater on-road aggressions.

Given the likely increase in the number of older drivers over the next decades, safety will be improved most by strategies aimed at the entire driving population with older drivers in mind, rather than relying on costly screening programmes to identify the relatively small numbers of impaired older people who continue to drive. To generate ideas for further work and intervention we might benefit from looking to the intended activities and policies of key road safety organisations. The U.S. National Highway Traffic Safety Board's 'Older Driver Safety Plan' [113] sets out their priorities are to address 5 key areas: *screening and assessment, licensing, medical providers, public education and programme promotion* and *other activities.* This set of priorities, or the WHO four element framework: *exposure, probability of crash, probability of injury, and injury outcome* [36] may provide useful guidance examples.

An analysis of STATS19 data relating to injury collisions caused by over-60s in Suffolk 2005-7

1. Introduction

A sample of STATS19 collision data relating to the Suffolk area covering the years 2005, 2006 and 2007 was provided by Suffolk County Council. The dataset included all collisions which included both an individual of 60 or over, and an injury, regardless of the blameworthiness of the individual aged 60+, and regardless of the role of the injured party within the collision.

Data was extracted relating to collisions in which the individual aged 60+ was the driver of the vehicle designated as at-fault in the police report. The rest of the data was not included in the analysis because in many cases the individual of 60+ had played no active part in the collision, for example if they were a passenger. The aim of the study was to look at the risks posed by and to older motorists, therefore including these cases would have polluted the data.

A number of data streams were extracted:

- Day of week
- Time of day
- Number of vehicles involved
- Number of casualties
- Number of fatalities
- Weather conditions
- Road surface conditions
- Road type
- Lighting conditions
- Age of driver
- Breath test status
- Collision type

All the data streams except collision type were entered exactly as they appeared on the STATS19 reports. Collision type was rated by the researcher based on the descriptive paragraphs on each report, and the allocation of “Vehicle 1” status (denoting the vehicle causing the collision). The initial collision type analysis resulted in over 50 categories, which were then re-evaluated and brought down to 28 categories.

2. Overall collision analysis

The overall collision statistics for drivers over 60 were briefly analysed for frequency of accident type, and grouped by situational data provided in the police reports. These analyses are considered in turn.

2.1 Fatalities

17 out of 745 (2.3%) the collisions studied involved a fatality. Collision statistics show that in general, in the US approximately 0.7% of all collisions involve a fatality (NHTSA, 2005). In the UK in 2006, there were 189,161 injury collisions, in which 3172 people were killed (DfT, 2007), indicating that around 1.7% of injury collisions involve a fatality. This shows that older drivers are at greater risk of causing a fatal collision compared with the general driving population.

2.2 Casualties

The majority of older drivers' collisions involved one casualty (71%). In many cases the sole casualty was the older driver themselves. 21.3% involved two casualties, with 7.6% involving three or more. Research shows that older drivers are at greater risk of injury when involved in a collision due to increased frailty, and it can take much longer for them to recover from their injuries compared to younger people.

2.3 Number of vehicles

The analysis indicated that 25.4% of the injury collisions caused by older drivers were single-vehicle incidents. 63.5% involved two vehicles, and 11.1% involved three or more vehicles. This data is not necessarily fully representative of the situation in itself because the collision reports can count vehicles that are parked and unattended which are damaged during the incident.

2.4 Weather

The collision data showed that 86.3% of collisions occurred in fine, dry weather, with 10.6% happening when it was raining. 0.8% took place in fog, a further 0.8% in snow, and weather conditions were not stated for the remaining 1.5%.

2.5 Day of week

The most risky day of the week for older drivers was Friday, with 19.2% of at-fault injury collisions for over 60s occurring on that day. Next was Wednesday (17.6%), followed by Monday (17.0%). Thursday (13.7%) and Tuesday (12.1%) were moderately risky, with weekends presenting the lowest risk (Saturday = 11.0%, Sunday = 9.4%).

2.6 Road type

Each road type was considered in turn, to establish where the majority of older driver collisions take place. The highest rate was on single carriageway roads (79.6%), which are likely to be most commonly driven roads, so this high proportion may reflect drivers' level of exposure to this road type. Dual carriageways accounted for 10.1% of collisions, with 5.5% taking place on roundabouts. 3.4% of the collisions studied took place in one-way streets.

2.7 Lighting

The lighting conditions for each collision were recorded on the report forms. 85.0% of the collisions occurred in daylight, with 5.9% taking place in darkness on unlit roads. 8.7% of collisions occurred in darkness on roads with street lights lit. Again, the high proportion of collisions taking place in daylight is likely to reflect the proportion of driving that older people do in the hours of daylight and darkness. The elevated proportion of collisions taking place at night on unlit roads compared to lit ones indicate that street lighting is very important in risk reduction, especially for older drivers as they tend to suffer visual declines which are exacerbated by low light conditions. These findings may also be a product of reduced speeds in lit areas, which tend to be far more built-up than unlit roads and often have a speed limit in place.

2.8 Time of day

The time of day at which each collision occurred was grouped into 6 time slots. The number and percentage of collisions taking place in each time slot are shown in Table 1.

Table 1. Number and percentage of collisions by time of day

Time of day	No. of collisions	Percentage of collisions
02.00 - 05.59	7	0.9
06.00 - 09.59	138	18.5
10.00 - 13.59	233	31.3
14.00 - 17.59	271	36.4
18.00 - 21.59	77	10.3
22.00 - 01.59	19	2.6

These findings indicate that the majority of over 60s at-fault injury collisions occur between 10.00 and 17.59 (combined 67.7%), with a further 18.5% occurring between 06.00 and 09.59. This is likely to be due to increased driving exposure during the daytime, but the considerable risk during the 06.00 – 09.59 slot may also be due to increased cognitive demand associated with driving during the busy morning period.

2.9 Breath test

The police data recorded whether a sample of breath was taken and analysed for alcohol at the scene of each collision. Failure of the breath test was rare among the older drivers (0.8%), with 65.1% passing the test. 33% did not take a breath test, and a further 1.1% were unable to do so on account of being deceased.

2.10 Type of collision

Collisions were grouped into 28 broad types, in order to establish which kinds of collisions were most likely to be caused by over 60s. Results are shown in Table 2.

The results show that the highest frequency of at-fault injury collisions were collisions taking place during right turns (20.3%), followed by rear-end collisions whereby the older driver collided with the rear of the vehicle in front (19.1%). Research shows that older drivers tend to have more difficulty with situations involving high cognitive demand, such as junctions, and cognitive decrements increase risk to a greater extent during a right-turn manoeuvre as hazard monitoring must be more active and a greater number of information streams must be processed simultaneously. A number of collisions were categorised as “pulling out on a vehicle at an intersection” if it appeared to be a collision involving a left turn or if the direction of turn was not clearly specified. If this group is combined with the right-turn group, collisions at junctions account for 30% of all over 60s’ at-fault injury collisions, supporting previous research findings.

Loss of control was also cited as the causal factor for 9.7% of collisions, indicating that older drivers may have difficulties handling their vehicles in certain situations, or that they do not monitor hazards effectively enough to adapt their driving to meet the requirements of an emerging situation, resulting in a loss of control and ultimately a collision.

Table 2. Frequency of each type of collision

	No. of collisions	Percentage of collisions
Hit cyclist in carriageway	8	1.1
Hit pedestrian	17	2.3
Hit object or parked vehicle	12	1.6
Fell off (2 wheeled vehicle)	5	.7
Head on	9	1.2
HGV jack knifed	2	.3
Hit accelerator not brake	10	1.3
Hit cyclist at intersection	6	.8
Hit pedestrian at intersection	6	.8
Hit side of car on roundabout	7	.9
Illegal manoeuvre	3	.4
Lost control	72	9.7
Miscellaneous	25	3.4
Opened door onto cyclist	5	.7
Overtaking	11	1.5
Passed out	23	3.1
Pedestrian stepped out	45	6.0
Pulled out on vehicle at intersection	72	9.7
Ran red light	7	.9
Rear ender	142	19.1
Right turn	151	20.3
Reversed into vehicle	7	.9
Reversed into pedestrian	11	1.5
Sideswipe	21	2.8
Skidded	23	3.1
Scooter	6	.8
Strayed across centre of carriageway	36	4.8
Wrong way	3	.4
Total	745	100.0

6% of collisions studied involved older drivers colliding with pedestrians who stepped out into the carriageway ahead of them. This may be attributable to reduced hazard monitoring, consistent with previous research which indicates that as drivers age, their cognitive processing abilities diminish and they lose the ability to monitor and prioritise all hazards within their field of view. This may cause them to focus primarily on hazards within the carriageway, reducing their chances of observing a potential hazard emerging from the side of the road. Decreases in visual abilities, such as short-sightedness or reduction in field of vision may also contribute to these incidents, as well as deterioration in reaction time in response to an immediate hazard.

4.8% of the collisions were attributed to straying across the centre of the carriageway for undetermined reasons and colliding with objects or vehicles on the far side of the road. This is likely to be related to physiological impairment resulting from illness, but these incidents were grouped separately unless physical illness was explicitly stated on the collision report form. If this group is combined with the group who were stated to have “passed out”

behind the wheel (3.1%), potentially 7.9% of the collisions studied could be attributed to physical health problems resulting in a loss of vehicle control.

2.11 Age by proportion of collisions

In these preliminary analyses, all drivers over 60 have been counted as one group, but of the at-fault injury collisions caused by drivers over 60 in Suffolk in the years 2005 – 2007 inclusive, 51.7% were caused by drivers in their 60s, 31.5% by drivers in their 70s, 15.7% by those in their 80s and 1.1% by drivers aged 90 or above.

Due to the very low proportion of collisions caused by drivers of 90 and above, for the purposes of more detailed analysis, 3 groups will be used – drivers aged 60 to 69, drivers aged 70 to 79, and drivers of 80+.

In the next section, the data is broken down by age group, in order to identify age-related trends in collision causation.

3. Analysis of collisions by age group

In this section, the collisions of drivers in their 60s, drivers in their 70s and drivers of 80 and above were compared.

3.1 Fatalities

One way ANOVA indicated that collisions caused by drivers over 80 were significantly more likely to involve a fatality than those caused by those in their 70s. Significance was not achieved in relation to differences between over 80s and drivers in their 60s, possibly due to inequality of group sizes. The means indicated the mean fatality level of drivers in their 60s was approximately half that of those over 80, with drivers in their 70s displaying the lowest mean fatality rate. This may be because drivers in their 70s have greater caution compared with those in their 60s as a result of an awareness of possible age-related declines, and the impact of the onset of these declines may not be having as great an impact on risk as for drivers over 80.

Table 3. Mean number of fatalities per collision by age group

Age group	No. of cases	Mean fatalities per collision
60-69	385	0.026
70-79	235	0.004
80+	125	0.048

3.2 Casualties

A one-way ANOVA was used to investigate differences in numbers of casualties involved in collisions caused by drivers in their 60s, those in their 70s and those over 80. No significant differences in the mean number of casualties involved in each collision were found between age groups.

3.3 Number of vehicles

The findings of the ANOVA investigating group differences in the number of vehicles involved in collisions attributed to drivers from each age group found significant differences between drivers in their 60s and in their 70s. Collisions caused by drivers in their 60s involved significantly fewer vehicles compared with those caused by drivers in their 70s. Significant differences were not found for drivers over 80, but the lower number of cases for this group makes it harder for statistical tests to achieve significance. The means suggest that drivers over 80 are similar to drivers in their 70s in terms of the number of vehicles involved in their collisions.

The increased number of vehicles in collisions caused by drivers over 70 suggests that the average severity of these collisions tends to be higher than those of drivers in their 60s, and is consistent with previous research indicating that older drivers tend to have collisions in high-demand situations where there are lots of hazards (including other vehicles) such as at junctions.

Table 4. Mean number of vehicles involved per collision by age group

Age group	No. of cases	Mean no. of vehicles per collision
60-69	385	1.820
70-79	235	1.970
80+	125	1.940

3.4 Weather

Collision statistics were examined to determine whether a relationship existed between age group and frequency of collisions in different weather conditions. The raw data is provided in Table 5.

Table 5. Number of collisions in each weather condition by age group

Weather	60-69	70-79	80+
Fine	337	200	106
Rain	37	28	14
Fog	4	1	1
Snow	2	2	2

Due to the inequality of group sizes, the data from the 70 to 79 group and the 80+ group were adjusted to be comparable with the 60 to 69 group. The adjusted data is shown in Table 6.

Table 6. Adjusted number of collisions in each weather condition by age group

Weather	60-69	70-79	80+
Fine	337	328	326.5
Rain	37	45.92	43.12
Fog	4	1.64	3.08
Snow	2	3.28	6.16

The difference in numbers of collisions in each weather condition between age groups was very small, which indicates that no age group is significantly more susceptible to collisions in adverse weather conditions. Findings for road surface conditions (dry, damp, icy) also failed to detect differences between age groups.

3.5 Day of week

The majority of collisions caused by drivers in their 60s occur on Fridays, while for drivers in their 70s the risk is highest on Wednesdays. Drivers over 80 had the highest frequency of collisions on Tuesdays. Sunday had the lowest rate of at-fault injury collisions across all age groups, followed by Saturday. This may be due to lower volume of traffic at weekends, allowing older drivers more time and space to manoeuvre thereby placing less demand on their cognitive processing abilities.

3.6 Road type

Collisions were analysed by the type of road on which they occurred. Results were adjusted to take account of differences in group size and are shown in Table 7.

Table 7. Adjusted number of collisions on each road type by age group

Road type	60-69	70-79	80+
Dual carriageway	36	49.2	27.72
3 lanes	4	4.92	0
One way	12	19.68	3.08
Roundabout	20	21.32	24.64
Single carriageway	311	287	329.56
Single track road	0	3.28	0

Drivers over 80 were least likely to cause a collision on dual carriageways, 3 lane roads and one way streets, but were the most likely to cause a collision on roundabouts and single carriageways. The number of collisions taking place on single track roads was so low that it was not possible to draw reasonable conclusions relating to this road type (n=2). Drivers in their 70s were at highest risk of causing a collision on dual carriageways, 3 lane roads and one way streets. The reduction in risk for over 80s may be due to a self-selection bias – they may tend to avoid these types of road wherever possible as they are aware that they could present a higher risk.

3.7 Light conditions

In daylight, drivers in their 60s were slightly less likely to cause a collision compared with drivers over 70, but at night they were more likely to do so. On roads where street lights were present and lit, drivers in their 60s were a third more likely to cause a collision compared with over 80s, and over twice as likely compared with drivers in their 70s. On unlit roads, drivers in their 60s displayed almost twice the risk of drivers over 70. This may be due to exposure – as drivers get older, they may be less likely to choose to drive at night, particularly on unlit roads. Adjusted collision rates are shown in Table 8.

Table 8. Adjusted number of collisions under each lighting condition by age group

Light conditions	60-69	70-79	80+
Daylight	313	346.04	335.72
Night (street lights)	29	13.12	21.56
Night (unlit)	42	24.6	24.64

3.8 Time of day

Collisions were divided into 6 groups based on the time of day at which they occurred. Adjusted data is shown in Table 9.

Table 9. Adjusted number of collisions at each time of day by age group

Time of day	60-69	70-79	80+
02.00 - 05.59	6	1.64	0
06.00 - 09.59	83	63.96	49.28
10.00 - 13.59	100	136.12	154
14.00 - 17.59	135	144.32	147.84
18.00 - 21.59	48	31.16	30.8
22.00 - 01.59	13	8.2	3.08

The data shows that between the hours of 22.00 and 09.59, drivers in their 60s are at greater risk of causing a collision compared with over 70s. Over 80s were at the lowest risk during these hours. However, between the hours of 10.00 and 21.59, drivers in their 60s were at the lowest risk of causing a collision. Between 10.00 and 13.59 there were marked differences in risk between all three groups, with risk increasing with age, but between 14.00 and 21.59 the differences between drivers in their 70s and drivers over 80 were minimal.

3.9 Collision type

An analysis was carried out to compare the relative number of each type of collision caused by drivers in each age group. The actual number of recorded collisions for each age group were very unequal (60 – 69 n = 385, 70 – 79 n = 235, 80+ n = 125), so the 60 – 69 group was used as the benchmark for each collision type. The proportional number of collisions caused by members of the other two age groups (had the groups been of equal size) was extrapolated using the absolute number of collisions for each group multiplied by a factor calculated by dividing the number of participants in the benchmark group by the number of participants in each of the other two groups.

Table 10. Proportional collision rates for each type of collision by age group

Collision type	**60-69**	**70-79**	**80+**
Hit cyclist in carriageway	5	4.92	0
Hit pedestrian	9	6.56	12.32
Hit object or parked vehicle	6	9.84	0
Fell off (two wheeled vehicle)	3	1.64	3.08
Head on collision	4	4.92	6.16
HGV jack-knifed	2	0	0
Hit accelerator not brake	2	11.48	3.08
Hit cyclist on roundabout	5	1.64	0
Hit pedestrian at intersection	3	4.92	0
Hit car on roundabout	1	4.92	9.24
Illegal manoeuvre	0	3.28	3.08
Lost control	42	37.72	21.56
Miscellaneous collision	17	9.84	6.16
Opened car door on cyclist	3	1.64	3.08
Overtaking	6	3.28	9.24
Passed out at wheel	8	9.84	27.72
Pedestrian stepped out	31	14.76	15.4
Pulled out on vehicle at intersection	37	29.52	52.36
Ran red light	2	3.28	9.24
Rear end collision	71	82	64.68
Right turn	63	101.68	80.08
Reversed into vehicle	2	3.28	9.24
Reversed into pedestrian	7	6.56	0
Sideswipe	14	8.2	6.16
Skidded	17	8.2	3.08
Invalid scooter collision	3	1.64	6.16
Strayed across centre of carriageway	21	8.2	30.8
Wrong way in one-way street	1	1.64	3.08

This analysis indicated that drivers of different ages within the older driver population are more prone to certain types of accidents than others.

- Drivers over 80 were less likely to hit objects, parked vehicles or cyclists in the carriageway compared with drivers aged between 60 and 79. This may be due to increases in caution and lower speeds with increasing age.

- Driver over 80 were less likely to hit pedestrians and cyclists at junctions and roundabouts, although they were more likely to hit another vehicle on entry to a roundabout. Drivers aged 70 to 79 were less than half as likely to hit a cyclist at an intersection compared with 60 to 69 year olds, but over 50% more likely to hit a pedestrian at a junction. This may be attributable to problems in visual scanning and cognitive prioritisation in high-demand situations such as roundabouts and junctions, combined with a lack of awareness of age-related decline. Drivers in their 70s may be more cautious and more aware of vulnerable road users in the carriageway compared with those in their 60s, but their active hazard monitoring may not extend beyond the carriageway itself, thus increasing risk of colliding with a pedestrian unexpectedly entering the road. Drivers over 80 may be displaying lower risk as their awareness of age-related decline (and experience of dealing with it) may be greater, leading to increases in active attempts to reduce risk through hazard monitoring and speed reduction.

- Drivers over 80 were less likely to reverse into a pedestrian compared with those aged 60 to 79. Drivers over 70 were less likely to collide with a pedestrian who stepped out in the carriageway in front of them compared with drivers aged 60 to 69. This is also attributable to increased caution and reduced speed.

- Risk of skid-related collisions also decreased with age. The risk for those in the 60 to 69 decreased by over 50% in the 70 to 79 age group. The risk of the 70 to 79 group decreased by over half again for the over 80 group, to less than 20% of the risk of the 60 to 69 group. Drivers over 80 were just over half as likely to be involved in a collision caused by general loss of control of their vehicle compared with the other groups. This supports previous research findings which indicate as age increases, risk during complex traffic situations increases but general driving risk is not significantly increased.

- Risk of causing a collision through side-swiping another vehicle when changing lanes or merging with traffic decreased with age. The greatest difference was between the 60 to 69 group and the 70 to 79 group, with a smaller decrease in risk between the 70 to 79 and 80+ groups. This may be due to decreased exposure to multi-lane roads as older drivers tend to take shorter journeys in the car.

- Drivers over 80 were more than 30% more likely to hit a pedestrian in or at the side of the carriageway compared with drivers in their 60s. Drivers in their 70s displayed the lowest risk. This pattern was replicated for collisions involving overtaking but to greater effect – 60 to 69 year olds were nearly twice as likely to have a collision when overtaking compared with drivers in their 70s, but drivers in their 80s were nearly three times as likely to do so. The high risk of the oldest group may be due to a combination of visual problems and cognitive issues surrounding scanning for unexpected hazards. 60 to 69 year olds may not be aware of age related declines and their risk may be

increased as a result, with drivers in their 70s displaying greater awareness and implementing countermeasures to reduce their risk.

- Risk of causing a head-on collision (non-overtaking) increased with age. Drivers aged between 70 and 79 were nearly 20% more likely to have a head-on collision compared with those in their 60s, but drivers over 80 were over 50% more likely to do so. This may be explained in terms of increased risk of illness and impairment at the wheel. Police reports were often vague but of the collisions documented as caused by illness or impairment, over 80s were around 3 times as likely to be involved compared with the younger groups. Drivers in their 70s were nearly 20% more likely to be involved compared with those in their 60s.

- 60 to 69 year olds were far less likely to cause a collision as a result of carrying out an illegal manoeuvre compared with drivers over 70. This may be due to a lack of awareness of road rules among the older groups, or the result of confusion or panic if they get themselves into a difficult situation. Some of the police reports specified that drivers had proceeded the wrong way along a one-way street, so these cases were considered separately and it was found that their frequency increased with age. Drivers over 80 were at greatest risk, followed by drivers in their 70s. Those in their 60s were least likely to be involved in this kind of collision.

- Likelihood of running a red light and causing a collision increased with age. Drivers in their 70s were over 50% more likely to do so compared with those in their 60s, and over 80s were more than four-and-a-half times as likely to cause a collision in this way. This is likely to be a product of visual decrement or insufficient hazard monitoring and cognitive processing.

- Whilst the risk of reversing into a pedestrian was shown to reduce with age, the risk of reversing into another vehicle increases. 70 to 79 year olds were more than twice as likely and over 80s were more than four-and-a-half times as likely to reverse into another vehicle compared with drivers in their 60s. It may be that as drivers get older, they prioritise looking for vulnerable road users when reversing, and cannot process the information relating to other objects efficiently enough to avoid colliding with vehicles. Alternatively, they may experience vehicle control problems attributable to physiological decrements.

- Risk of causing a collision by pulling out in front of an oncoming vehicle at a junction was shown to be greatest in the over 80 group. Drivers in their 60s were approximately 75% as likely to do this, and those in their 70s displayed just over 50% of the risk of the over 80s. However this data should be considered in combination with the results relating to collisions involving right turns, as inconsistency in police reports meant that it was not possible to accurately establish whether a collision at a junction involved a left or right turn. Cases that explicitly stated that a right turn was involved were analysed separately, and findings showed

that drivers in their 60s were at the lowest risk, with those in their 70s at highest risk (over 50% greater) and over 80s involved in 25% more right-turn collisions compared with 60 to 69 year olds. When this data is combined, it shows that drivers in their 70s and those over 80 were at very similar risk of causing a collision when negotiating a junction, while those in their 60s were at considerably lower risk (60 – 69 = 100, 70 – 79 = 131.2, over 80 = 132.44). This supports the assumption that drivers find it harder to negotiate complex traffic situations as they grow older. This is likely to be due to cognitive decrements including a reduction in hazard monitoring and ability to process and prioritise information.

- Collisions involving invalid scooters were most prevalent among the over 80s, but the police data did not always indicate clearly whether the at-fault party was riding the scooter or collided with it, therefore it is not possible to draw conclusions on the basis of this finding.

- Drivers in their 70s were at lowest risk of straying across the centre of the carriageway and hitting an object on the far side. Drivers in their 60s were approximately two-and-a-half times more likely to do so, while over 80s were involved in over three-and-a-half times more of these collisions. However, it is difficult to determine the causal factors of these collisions, and it is possible that they could be grouped in with other kinds of collisions, such as loss of control or illness/impairment. The inconsistent nature of the police reports means they do not always provide enough detail to determine the true nature of the incident.

- Rear end collisions were prevalent among all older drivers groups, with drivers in their 70s displaying the highest risk, and over 80s the lowest. Differences between groups were not extreme, suggesting that rear end collisions were a similar problem for older drivers of all ages. It is likely that a lack of concentration and hazard prioritisation is responsible for the prevalence of this type of collision.

Conclusions and recommendations for future research

1. Conclusions

The findings of the literature review and the collision data analysis do, in many areas, correspond with one another and support the broad hypothesis that age-related declines have a detrimental effect on older driver risk. However, the literature review indicated that whilst there is a considerable body of published research on older driver risk, much of the research focuses on the same few key issues, i.e. physiological declines, such as issues with visual ability (Part A, 4.1.1) and cognitive processing ability (Part A, 4.1.3). The debate surrounding the *extent* to which driver risk increases with age continues to rage, but the overarching finding is that older drivers are at particularly high risk of certain kinds of collisions, particularly those occurring in high-demand situations such as town driving (Part A, 4.2). The findings of the collision analysis suggest that older drivers exert a degree of self-regulation in terms of their driving choices (Part A, 5.1) and indeed whether they continue to drive at all (Part A, 5.2).

The literature does not offer a great deal in terms of comparing the best approaches to assess older drivers' competence, or how to deal with age-related declines. The Suffolk Grand Driver project is taking the lead in trialling comprehensive assessment methods, and results of the assessments and data relating to effectiveness of interventions will inform the field as findings emerge in due course. In the meantime, there are a number of broad conclusions that can be drawn from the literature in combination with the collision data analysis, and these provide a basis for suggestions for future research.

2. Key findings:

- The fatality rate for collisions caused by over 60s is higher than the overall rate for all collisions combined (Part A, 2.2.4, Part B 2.1).

- Most of these collisions are single vehicle, single casualty (Part B, 2.2, 2.3).

- Weekdays are more risky for older drivers than weekends, particularly during the daytime, but at night, unlit roads are particularly dangerous (Part B, 2.5, 2.7, 2.8).

- The majority of older-driver collisions involve rear-end collisions, or junctions, or both (Part A, 4.3.3, Part B, 2.10, 3.9). The next most common types of collisions are loss-of-control collisions, and colliding with pedestrians who step into the road.

- Ill-health plays a part in a significant number of older-driver collisions (Part A, 4.1, Part B, 2.10, 3.9)

- Collision rates decrease as age increases, supporting the suggestion that drivers self-select themselves to cease driving (Part A, 5.1, 5.2, Part B, 3).

- Risk at roundabouts and on single carriageways (particularly at junctions) increases with age, but risk on dual carriageways and 3 lane roads decreases as the older-driver population age, which suggests that as drivers get older they may decrease their use of larger and faster roads (Part B, 3.6, 3.9).

- The younger members of the older driver population are at slightly less risk of collision than the older ones during daylight hours, but at night, the older ones are at much lower risk (especially on unlit roads). This may be due to self-selection or adaptive strategies (Part A, 5.1, 5.2, Part B, 3.7, 3.8).

- Analysis of collision type suggested that over 80s are more likely to use increased caution and decreased speed, but their Hazard Monitoring may not extend far along the carriageway or beyond the boundary of the carriageway (Part A, 4.1.1, Part B, 3.9). Processing of hazard information seems to suffer as age increases (illustrated by increases in running red lights, hitting pedestrians, rear end collisions etc.). High demand situations (i.e. junctions) prove particularly risky as hazards must be monitored, processed and prioritised under time pressure – a skill which deteriorates significantly with age (Part A, 4.2, Part B, 3.9).

3. Recommendations:

- Aim to reduce older driver exposure to high-demand situations through journey planning – route planning, time-of-day, day of week

- Emphasise hazard monitoring skills – hazard perception test style training

- Focus on cognitive assessment and “brain training” – work with drivers who do not show cognitive impairment as well as those who do, as awareness is key and prevention is preferable to (attempted) cure

- Encourage older drivers to be more aware of potential risks of driving when unwell, and urge GPs to provide more comprehensive health assessment for older drivers

- Focus on making the younger segment of the older driver population fully aware of potential age-related decrements in driving performance, to facilitate behavioural change

- Ensure that older drivers are comfortable with the automation in their vehicle – basic vehicle control skills can be compromised if added stress is placed on the driver as a result of in-vehicle confusion

4. Suggestions for future research:

- Investigate which driving situations older drivers perceive to be the most risky, and compare with research findings

- Identify key factors in the decision to stop driving:
    - In perceived risky situations
    - Completely

- Identify and evaluate different methods of cognitive assessment and training

- Conduct a longitudinal study comparing effects of increased awareness of age-related decrements combined with cognitive training on samples starting at different ages within the older-driver spectrum

- Develop and evaluate behavioural and possibly technological strategies for improving hazard processing in high-demand situations

References

1. Adler, G. & Rottunda, S. (2006). Older adults' perspectives on driving cessation. ***Journal of Aging Studies***, 20, 227-235
2. Lerner, M., Morrison, M. & Raffe, D. (1990). ***Older Drivers' Perception of Problems in Freeway Use***. Washington DC: AAA Foundation for Road Safety
3. Cobb, R.W. & Coughlin, J.F. (1998). Arer elderly drivers a road hazard?: problem definition and political impact. ***Journal of Aging Studies***, 4, 411-27
4. Lister, R. (1999). Loss of ability to drive following a stroke: the early experiences of three elderly people on discharge from hospital. ***British Journal of Occupational Therapy***, 62 (11), 514-520
5. 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
6. Carberry, T.P., Wood, J.M. & Watson, B.C. (2004). Eye disease and driving performance: correlates between insight and capability in drivers with glaucoma. 2004 Road Safety Research, Policing and Education Conference: Perth, Australia
7. Owsley, C. & McGwin, G., Jr. (1999). Visual impairment and driving. ***Survey of Opthalmology***, 43 (6), 535-550
8. Szlyk, J.P., Taglia, D.P., Paliga, J., Edward, D.P. & Wilensky, J.T. (2002). Driving performance in patients with mild to moderate glaucomatous clinical vision changes. ***Journal of Rehabilitation Research and Development***, 39 (4), 467-482
9. Underwood, G., Phelps, N., Wright, C., van Loon, E. & Galpin, A. (2005). Eye fixation scanpaths of younger and older drivers in a hazard perception task. ***Ophthalmic and Physiological Optics***, 25, 346-356
10. Wood, J.M. (1999). How do visual status and age impact on driving performance as measured on a closed circuit driving track? ***Ophthalmic and Physiological Optics***, 19, 34-40
11. Andersen, G.J., Cisneros, J., Saidpour, A. & Atchley, P. (2000). Age-related differences in collision detection during deceleration
12. McGwin, G., Jr., Owsley, C. & Ball, K. (1998). Identifying crash involvement among older drivers: agreement between self-report and state records. ***Accident Analysis and Prevention***, 36 (6), 781-791
13. Anthony Ryan, G., Legge, M. & Rosman, D. (1998). Age related changes in drivers' crash risk and crash type. ***Accident Analysis and Prevention***, 30 (3), 379-387
14. Preusser, D.F., Williams, A.F., Ferguson, S.A., Ulmer, R.G. & Weinstein, H.B. (1997). Fatal crash risk for older drivers at intersections. ***Accident Analysis and Prevention***, 30 (2), 151-159
15. Dellinger, A.M., Kresnow, M., White, D.D. & Sehgal, M. (2004). Risk to self versus risk to others: How do older drivers compare to others on the road? ***American Journal of Preventive Medicine***, 26 (3), 217-221
16. Mortimer, R.G. & Fell, J.C. (1989). Older drivers: Their night fatal crash involvement and risk. ***Accident Analysis and Prevention***, 21 (3) 273-282
17. 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
18. Ball, K.K. & Owsley, C.C. (2003). Driving competence: it's not a matter of age. ***Journal of the American Geriatrics Society***, 51 (10), 1499–1501
19. McGwin, G., Jr. & Brown, D.B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. ***Accident Analysis and Prevention***, 31 (3) 181-198

20. West, C.G., Gildengorin, G., Haegerstrom-Portnoy, G., Lott, L.A., Schneck, M.E., &. Brabyn, J.A. (2003). Vision and Driving Self-Restriction in Older Adults. ***Journal of the American Geriatrics Society***, 51 (10), 1348–1355
21. Borowsky, A., Shinar, D. & Oron-Gilad, T. (2007). Age, skill, and hazard perception in driving. ***Proceedings of the Fourth Symposium on Human Factors in Driver Assessment, Training and Vehicle Design***
22. Wang, C., Kosinski, C., Schwartzberg, J. & Shanklin, A. (2003). ***Physician's guide to assessing and counseling older drivers***. Washington DC: National Highway Traffic Safety Administration
23. Tuokko, H., McGee, P. Stepaniuk, J. & Benner, E. (2007). ***The older and wiser rider: an examination of transportation for older drivers***. Centre on Aging; University of Victoria
24. Burkhardt J.E. and McGavock A.T. (1999). Tomorrow's Older Drivers, Who?, How Many?, What Impacts? ***Transportation Research Record 1693***. National Research Council, Washington, DC. 62-70
25. Lyman, S., Ferguson, S., Braver, E. & Williams, A. (2002). Older driver involvements in police reported crashes and fatal crashes: trends and projections. ***Injury Prevention***, 8,116–120
26. Lyman J.M., McGwin, G. & Sims R.V. (????) Factors related to driving difficulty and habits in older drivers. ***Accident Analysis and Prevention***, 33, 413–21
27. 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, 3110-3123
28. Owsley, C., Ball, K., McGwin, G., Jr., 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, 1083-1088
29. Stutts, J.C., Stewart, J.R. & Martell, C. (1990). Cognitive test performance and crash risk in an older driver population. ***Accident Analysis and Prevention***, 30 (3), 337–346
30. Williams, A.F. & Carsten, O. (1989). Driver age and crash involvement. ***American Journal of Public Health***,79, 326–327
31. Al Madhani, H.M.N. (2000). Influence of drivers' comprehension of posted signs on their safety related characteristics. ***Accident Analysis and Prevention***, 32, 575-581.
32. Office for Population Censuses and Surveys (1992). ***1989 Based National Population Projections***, PP2, NO17. HMSO
33. Noble, B. (2000) Travel characteristics of older people. ***Transport Trends***. DTLR
34. Department for Transport (2004). ***Older drivers: a literature review***. Road Safety Research Report No.25. Department for Transport
35. Benekohal, R.F., Michaels, R.M., Shim, E. & Resende, P.T. (1994). Effects of aging on older drivers' travel characteristics. ***Transport Research Record***, 1438, 91-98
36. World Health Organization (2004). ***World Report on Traffic Injury Prevention***. Geneva: WHO
37. Herriots, P. (2005). Identification of vehicle design requirements for older drivers. ***Applied Ergonomics***, 36 (3), 255-262
38. Jacobs, G., Aeron-Thomas, A. & Astrop, A. (2000). ***Estimating Global Road Fatalities***. London: Transport Research Laboratory, 2000. (TRL Report 445)
39. Tay, R. (2006). Ageing drivers: storm in a teacup? ***Accident Analysis and Prevention***, 38, 112-121
40. Dulisse, B. (1997). Older drivers and risk to other road users. ***Accident Analysis and Prevention***, 29 (5), 573-582

41. Nasvadi, G.E. & Vavrik, J. (2007). Crash risk of older drivers after attending a mature driver education program. ***Accident Analysis and Prevention***, 39 (?), 1073-1079
42. Baker, T.K., Falb, T., Voas, R. & Lacey, J. (2003). Older women drivers: fatal crashes in good conditions. ***Journal of Safety Research***, 34, 399-405
43. Organisation for Economic Co-operation and Development (2001). ***Ageing and transport: mobility needs and safety issues***. Paris: OECD Scientific Expert Group
44. Al-Madani, H. M. N. (2001). Prediction of drivers' recognition of posted signs in five Arab countries. ***Perceptual and Motor Skills***, 92, 72-82
45. Langford, J. & Koppel, S. (2006). The case for and against mandatory age-based assessment of older drivers. ***Transportation Research Part F***, 9, 353-362
46. Reinfurt, DW; Stewart, JR; Stutts, J; Rodgman, EA (2000) ***Investigations of crashes and casualties associated with older drivers***. Chapel Hill: University of North Carolina Highway Safety Research Centre
47. Cerelli, E. (1989). ***Older drivers, the age factor in traffic safety***. Technical Report DOT HS 807 402. Washington DC: National Highway Traffic Safety Administration
48. Staplin, L., Lococo, K., Byington, S., and Harkey, D. (2001). ***Highway Design Handbook for Older Drivers and Pedestrians.*** Federal Highway Administration. Report No. FHWA-RD-01- 103
49. Pöystia, L., Rajalina, S. & Summala. H. (2005). Factors influencing the use of cellular (mobile) phone during driving and hazards while using it. ***Accident Analysis and Prevention***, 37 (1), 47-51
50. Madden, D.J. (2007). ***Aging and Visual Attention***. Current Directions in Psychological Science, 16 (2), 70-74
51. Jonah, B. (1986). Accident risk and risk-taking behaviour among young drivers. ***Accident Analysis and Prevention***, 18 (?), 255-271
52. Lyman, S., Ferguson, S.A., Braver, E.R. & Williams, A.F. (2002). ***Injury Prevention***, 8, 116-20
53. Eby, D.W., Molnar, L.J., Shope, J.T., Vivoda, J.M. & Fordyce, T.A. (2003). Improving older driver knowledge and self awareness through self assessment: the driving decisions workbook. ***Journal of Safety Research***, 34, 371-381
54. 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 of Aging***, 25 (1), 65-76
55. Johnson, J.E. (1995). Rural elders and the decision to stop driving. ***Journal of Community Health Nursing***, 12 (3), 131 – 138
56. Marottoli, R.A., Mendes de Leon, CF., Glass, T.A., Williams, C.S., Cooney, L.M., Berkman, L.F. & Tinetti, M.E. (1997). Driving Cessation and Increased Depressive Symptoms: Prospective Evidence from the New Haven EPESE. ***Journal of the American Geriatrics Society***, 45, 202-6
57. Hakamies-Blomqvist, L. & Whalstrom, B. (1998). Why do older drivers give up driving? ***Accident Analysis and Prevention***, 30 (?), 305-31
58. Owsley, C., Stalvey, B., Wells, J., & Sloane, M. (1999). Older drivers and cataract: Driving habits and crash risk. ***Journals of Gerontology Series A: Biological Sciences and Medical Sciences,*** 54 (4), 203-211
59. Parker, D., MacDonald, L., Sutcliffe, P. & Rabbitt, P. (2001). Confidence and the older driver. ***Ageing and Society,*** 21 (2), 169-182
60. Marottoli, R.A. & Richardson, E.D. (1998). Awareness of, and confidence in, driving ability among older persons. ***Accident Analysis and Prevention***, 30, 331-6

61. 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, 441-456
62. Ruechel, S. & Mann, W.C. (2005). Self-regulation of driving by older persons. ***Physical & Occupational Therapy in Geriatrics***, 23 (2/3), 91-101
63. Holland, C. & Rabbitt, P. (1992). People's awareness of their age-related sensory and cognitive deficits and the implications for road safety. ***Applied Cognitive Psychology***, 6, 217-231
64. Banks, P.M., Moore, L.A., Liu, C. & Wu, B. (2004). ***South African Optometrist***, 63 (2), 58□64
65. Long, G.M. & Crambert, R.F. (1990). The nature and basis of age-related changes in dynamic visual acuity. ***Psychology and Aging***, 5, 138-143
66. Wood, J.M. (2002). Age and Visual Impairment Decrease Driving Performance as Measured on a Closed-Road Circuit. ***Human Factors***, 44 (3), 482-49
67. McCloskey, L.W., Koepsell, T.D., Wolf, M.E. & Buchner, D.M. (1994). Motor vehicle collision injuries and sensory impairments of older drivers. ***Age and Ageing***, 23, 267-273
68. Sekuler, R. & Blake, R. (1985). ***Perception***. New York: Alfred J. Knopf
69. Johnson C. A., & Keltner J. L. (1983) Incidence of visual field loss in 20000 eyes and its relationship to driving performance, ***Archives of Ophthalmology***, 101, 371-375
70. Szlyk, J. P., Alexander, K. R., Severing, K., & Fishman, G. A. (1992). Assessment of driving performance in patients with retinitis pigmentosa. ***Archives of Ophthalmology***, 110, 1709-1713
71. Kline, D.W. & Scialfa, C.T. (1997). Sensory and perceptual functioning:basic research and human factors implications. In A.D. Fisk & W.A. Rogers (Eds). ***Handbook of Human Factors and the Older Adult***, pp.27-54. San Diego: Academic Press
72. Ball, K. & Owsley, C. (1991) Identifying correlates of accident involvement for the older driver. ***Human Factors***, 33: 583-595
73. Ball, K., Beard, B., Roenker, D., Miller, R., & Griggs, D. (1988). Age and visual search: Expanding the useful field of view. ***Journal of the Optical Society of America***, 5, 2210–2219
74. Mortimer, R. G. (1989). Older Drivers' Visibility and Comfort in Night Driving: Vehicle Design Factors. ***Proceedings of the 39th Annual Meeting of the Human Factors Society***. Santa Monica: Human Factors Society,
75. Schieber, F. (1994). Age and Glare Recovery Time for Low Contrast Stimuli. ***Proceedings of the 38th Annual Meeting of the Human Factors and Ergonomics Society***. Santa Monica: Human Factors and Ergonomics Society
76. Collia, D.V., Sharp, J. & Giesbrecht, L. (2003). The 2001 national household travel survey: a look into the patterns of older Americans. ***Journal of Safety Research***, 34 (4), 461-470
77. Bendixen, R.M., Mann, W.C. & Tomita, M. (2005). The relationship of home range to functional status and cognitive status of frail elders. ***Physical and Occupational Therapy in Geriatrics,*** 23, 43-62
78. Cannon Hendrickson, C. & Mann, W.C. (2005). Changes over time in community mobility of elders with disabilities. ***Physical and Occupational Therapy in Geriatrics,*** 23, 75-89
79. Awadzi, K. & Garvan, C. (2006). Determinants of older driver safety from a socioecological perspective. ***Topics in Geriatric Rehabilitation***, 22 (1), 36-44
80. Sabback, F. & Mann, W.C. (2005). The influence of climate and road conditions on driving patterns in the elderly population. ***Physical and Occupational Therapy in Geriatrics,*** 23, 63-74

81. Schieber, F. (1994). High-priority research and development needs for maintaining the safety and mobility of older drivers. ***Experimental Aging Research***, 20, 35-43
82. National Highway Traffic Safety Administration (2006). ***Traffic Safety Facts 2006: Older Population***. Washington, DC: US. Department of Transportation, National Highway Transport Safety Administration
83. Brendemuhl, D., Schmidt, U. & Schenk, N. (1988). Driving behaviour of elderly motorists in standardised test runs under road traffic conditions. In: J. Rothengatter and R. de Bruin. (Eds). ***Road User Behaviour: Theory and Research***. Dordrecht: Van Gorcum
84. Brainin, P.A. (1980). ***Safety and Mobility Issues in Licensing and Education of Older Drivers***. Final Report DOT HS-805 492. Washington, DC: US. Department of Transportation, National Highway Transport Safety Administration
85. Schlag, B. (1993). Elderly drivers in Germany fitness and driving behaviour. ***Accident Analysis and Prevention****, 25*, 47-55
86. Welford, A. T. (1962). Changes in the speed of performance with age and their industrial significance. ***Ergonomics****, 5*. 139-145
87. Rabbitt, P.M.A. (1965) Age and discrimination between complex stimuli. In: A.T. Welford and J.E. Birren (Eds). ***Behaviour, Ageing and the Nervous System***. Springfield, Illinois: C.C. Thomas
88. Szafran, J. (1968). Psychophysiological studies of ageing in pilots. In G.A. Talland (Ed) ***Human Ageing and Behaviour: Recent Advances in Research and Theory***. New York: Academic Press
89. Kemp, B.J. (1973). Reaction time of young and elderly subjects in relation to perceptual deprivation and signal on versus signal off conditions. ***Developmental Psychology***, 8, 268-272
90. French, D.J., West, R.J., Elander, J. and Wilding, J.M. (1993). Decision making style, driving style and self-reported involvement in road traffic accidents, ***Ergonomics****,* 36 (6), 267-644
91. Odero, W., Garner, P. & Zwi, A. (1997). Road traffic injuries in developing countries: a comprehensive review of epidemiological studies. ***Tropical Medicine and International Health***, 2 (5), 445-460
92. Sivak, M., Olson, P.L. & Pastalan, L.A. (1981). Effects of driver age on night-time legibility of highway signs. ***Human Factors****,* 22 (5). 559-571
93. Sivak, M. & Olson, P.L. (1982). Night-time legibility of traffic signs: Conditions eliminating the effects of driver age and disability glare. ***Accident Analysis and Prevention****,*14, 87-93
94. Staplin, L., Breton, M.E., Haimo, S.F., Farber, E.I. and Byrnes, A.M. (1988) ***Age Related diminished capacities and driver performances***. Contract No. DTFH 61-86-c-00044 FHA
95. Rabbit, P., Carmichael, A., Jones, S. & Holland, C. (1996). ***When and Why Older Drivers Give Up Driving***. AA Foundation for Road Safety Research
96. Brayne, C., Dufouil, C., Ahmed, A., Dening, T.R., Chi, L.Y., McGee, M., & Huppert, F.A. (2000). Very old drivers: findings from a population cohort of people aged 84 and over. ***International Journal of Epidemiology***, 29(4), 704-707
97. Fell, J.C. (1976). A motor vehicle accident causal system: the human element. ***Human Factors***, 18, 85-94
98. Colsher, P. & Wallace, R.B. (1993). Geriatric assessment and driver functioning. ***Clinics in Geriatric Medicine***, 9, 365-375
99. Shinar, D. (1993). Traffic safety and individual differences in drivers' attention and information processing capacity. ***Alcohol, Drugs and Driving***, 9, 219-237

100. Richards, S.H. & Heatherington, K.W. (1988). Motorist understanding of railroad highway grade crossing traffic control devices and associated traffic laws. ***Transportation Research Record***, 1160, 52-59
101. Otani, H., Leonard, S.D., Ashford, V.L. & Bushore, M. (1992). Age difference in perception of risk. ***Perceptual and Motor Skills***, 74 (2), 587-594
102. Hofner, K. J. (1982). Causes of Traffic Violations. ***Arbeiten– aus– dam– verkehrspsychologischen–Institute***. 19 (6), 47-58
103. Al-Madani, H.M.N. & Al-Janahi, A.R. (2002). Assessment of drivers' comprehension of traffic signs based on their personal and social characteristics. ***Transportation Research Part F***, 5, 63-76
104. Hu, P.S., Trumble,.D.A., Foley, D.J., Eberhard, J.W. & Wallace, R.B. (1998). Crash risks of older drivers: a panel data analysis. ***Accident Analysis and Prevention,***30 (5), 569-581
105. Keall, M.D. & Frith, W.J. (2004). Adjusting for car occupant injury liability in relation to age, speed limit, and gender-specific driver crash involvement risk. ***Traffic Injury Prevention***, 5 (4), 336-342
106. Langford, J., Fitzharris, M., Newstead, S. & Koppel, S. (2004). Some consequences of different older driver licensing procedures in Australia. ***Accident Analysis and Prevention,***36 (5), 993-1001
107. Howell, W.C. (1997). Foreword, perspectives, and prospectives. In: Fisk, A.D. & Rogers, W.A. (Eds). ***Handbook of the Human Factors and the Older Adult***. San Diego: Academic Press, 1-6
108. Janke, M. (1991). Accidents, mileage and the exaggeration of risk. ***Accident Analysis and Prevention***, 23, 183-188
109. Stapling, L., Gish, K.W. & Joyce, J. (2008). 'Low mileage bias' and related policy implications – a cautionary note. ***Accident Analysis and Prevention***, 40, 1249-1252
110. Langford, J., Fitzharris, M., Koppel, S. & Newstead, S. (2004). Effectiveness of mandatory licence testing for older drivers in reducing crash risk among urban older Australian drivers. ***Traffic Injury Prevention,***5, 326-335
111. Langford, J., Koppel, S., Andrea, D. & Fildes, B. (2006). Determining older driver crash risk responsibility from police and insurance data. ***Traffic Injury Prevention,***7, 343-351
112. Lee, H.C., Lee, A.H., Cameron, D. & Li-Tsang, C. (2003). ***Journal of Safety Research***, 34, 453-459
113. National Highway Traffic Safety Administration (2005). ***Older Driver Traffic Safety Plan***. Washington, DC: US. Department of Transportation, National Highway Transport Safety Administration
114. viamonte
115. Clay, O.J., Wadley, V.G., Edwards, J., Roth, D.L., Roenker, D., & Ball, K.K. (2005). Cumulative metaanalysis of the relationship between Useful Field of View and driving performance in older adults. ***Optometry & Vision Science***, 82, 724-731
116. 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, 260-266
117. Bédard, M., Porter, M.M., Marshall, S., Isherwood, I., Riendeau, J., Weaver, B., Tuokko, H., Molnar, F. & Miller-Polgar, J. The combination of two training approaches to improve older adults' driving safety. ***Traffic Injury Prevention***, 9, 70-76
118. Dorn, L. (2005). Driving standards higher. In: L. Dorn (Ed). ***Driver Behaviour and Training (Vol. 2)***, p.471- 480

119. 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, 393-400
120. Christie, R. (2001). ***The effectiveness of driver training as a road safety measure: A review of the literature***. Royal Automobile Club of Victoria (RACV) Ltd. Victoria, Australia
121. Mayhew, D. R. & Simpson, H. M. (2002). The safety value of driver education and training. ***Injury Prevention***, 8, ii3-ii8
122. Kua, A., Korner-Bitensky, N., Desrosiers, J., Man-Son-Hing, M. & Marshall, S. (2007). Older driver retraining: a systematic review of evidence of effectiveness. ***Journal of Safety Research***, 38, 81-90
123. Simms, B. (1985). Perception and driving: theory and practice. Occupational Therapy, ***British Journal of Occupational Therapy***, 48, 363–366
124. McCloskey, L., Koepsell, T., Wolf, M. & Buchner, D. (1994). Motor vehicle collision injuries and sensory impairments of older drivers. ***Age and Aging***, 23, 267-273
125. Stelmach, G. & Nahom, A. (1992). Cognitive-motor abilities of the elderly driver. ***Human Factors***, 34, 53-65
126. Shaheen, S.A. & Niemeier, D.A. (2001). Integrating vehicle design and human factors: minimizing elderly driving constraints. ***Transportation Research Part C***, 9, 155-174
127. 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, 574-578
128. Lundberg, C., Hakamies-Blomqvist, L., Almkvist, O. & Johansson, KI. (1998). Impairments of some cognitive functions are common in crash-involved older drivers. ***Accident Analysis and Prevention***, 30, 371-377
129. Alvarez, F.J. & Fierro, I. (2008). Older drivers, medical condition, medical impairment and crash risk. ***Accident Analysis and Prevention***, 40, 55-60
130. Langford, J. & Koppel, S. (2006). Epidemiology of older driver crashes – identifying older driver risk factors and exposure patterns. ***Transportation Research Part F: Traffic Psychology and Behaviour***, 9, 309-321
131. Simms, B. (1993). Characteristics and driving patterns of drivers over 70. TRL Report PR46. Crowthorne: Transport Research Laboratory
132. Hakamies-Blomqvist, L. (1988). ***Fatal road accidents involving elderly drivers***. *Paper presented at the Commission of the European Communities Workshop on Errors in the Operation of Transport Systems*, Cambridge
133. Williams, A.F., Wells, J.K. & Lund, A.K. (1987). ***Accident Analysis and Prevention***, 19, 251-260