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Supporting older driver mobility and effective self-regulation

A review of the current literature

Dr Julie Gandolfi

Driving Research Ltd.

January 2020

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About the Author

Dr Julie Gandolfi is a Chartered Psychologist with a PhD in Human Factors from Cranfield University for research relating to psychometric assessment of police driver risk. In 2007 Julie founded Driving Research Ltd., specialising in consultancy on the development and evaluation of road safety initiatives, attitudinal and behavioural driver assessment and training, and incorporation of psychological theory and research into road safety education and interventions, working with a variety of clients including Unilever, Highways England, various Local Authorities and insurance underwriters. She has also worked closely with Cranfield University, lecturing on postgraduate degree courses including the MSc in Driver Behaviour and Education and the MSc in Automotive Systems Engineering.

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Disclaimer

Contents

List of Figures

List of Tables

Foreword

Keeping up with the latest developments in road safety thinking worldwide is a challenging task, and the safety of older drivers is no exception. Many countries around the world are grappling with the implications of an aging population – aging not just in the sense of older people making up a higher proportion of the population but aging also as life expectancy increases, meaning more of us expect to remain active well into older age. Increased longevity is challenging the very sense of what it means to be 'old'. For instance, according to DVLA records the number of people aged 90 or older holding a full driving licence in Great Britain already stands at 119,605 as of December 2019.

Dr Gandolfi's report tells us that while aging affects us as individuals in different ways, and at a different pace, some aspects of aging are inevitable – increased physical frailty and declining cognitive, physical and visual ability. These changes can both make us more vulnerable to more serious injury in the event of a collision and impair the skills we need as drivers. Hence we hear frequent calls for the introduction of compulsory re-testing for older drivers. But it is much easier to call for compulsory re-testing than it is to identify what form such re-testing should take.

This report reveals quite how hard it has proved to devise a test method that demonstrably reduces road safety risk, even when involving an extreme set of hurdles, as is the case for older Japanese drivers, who, after the age of 70, are required to take part in an education session, several vision tests and an on-road driving assessment. As Dr Gandolfi says: "Given the obvious challenges involved in creating a standardised, objective driver assessment that facilitates targeted interventions capable of helping older drivers to self-regulate effectively, it is necessary to turn attention to the resources that are readily available to assist older drivers in calibrating their own self-awareness and implementing appropriate self-regulatory behaviours."

In other words, we need to do all we can to make it easier for us to help ourselves. And that's particularly important when it comes to the design of in-car systems. The good news here is that in addition to an array of safety features designed to protect car occupants in the event of a collision, modern cars also offer an increasing wealth of driver-assist technology, gradually trickling down from high-end vehicles to the smaller, more affordable models. The challenge comes in making these systems easier to understand and operate, ideally making them so intuitive that recourse to the owner's manual only needs to be a last resort. Overall the key message is that it's important for us all to self-regulate ourselves and our driving as we get older, and that means getting regular health check-ups and eye tests long before we might start thinking of ourselves as being 'old'.

Steve Gooding

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Director, RAC Foundation

List of Abbreviations

AAA	American Automobile Association
AD	Alzheimer's disease
ADAS	advanced driver assistance systems
AV	autonomous vehicle
AVT	advanced vehicle technology
GDE	Goals for Driver Education
HAV	highly automated vehicle
HMI	human–machine interface
MCI	mild cognitive impairment
NHTSA	National Highway Traffic Safety Administration
OSCAR	'Outil de sensibilisation des conducteurs âgés aux capacités requises pour une conduite automobile sécuritaire et responsable' – literally 'Tool for the education of older drivers about the capabilities required for safe and responsible driving': an awareness tool for safe and responsible driving
OSCARPA	An adaptation of OSCAR for relatives of older drivers ('PA' referring to caregivers, French 'proches aidants')
PAPM	Precaution Adoption Process Model
RST	Reinforcement Sensitivity Theory
TOR	takeover request
UFOV	Useful Field of View
VMC	visual–motor co-ordination

1. Introduction

This report sets out to examine the current literature on age-related driver impairment relationships between vehicle technology and driver stress and confidence, and the effectiveness of interventions intended to mitigate the risk-increasing effects of age-related declines in physical and cognitive processes.

An earlier review, published by the RAC Foundation in 2010, studied the role of infrastructure in older driver risk, and concluded (1: 139) that:

> "there are key older-driver issues which are consistently problematic in a wide variety of traffic situations, i.e. visual problems, cognitive processing speed, cognitive overload, perceptual errors/confusion, mobility issues, frailty, etc. These factors have an impact on older driver risk in each of the areas investigated. This raises a rather fundamental question – is it practical to attempt to adapt the traffic environment to meet the needs of the older driver, or should the focus be on trying to equip the older driver to deal with the existing traffic environment more efficiently? It is likely that the optimal solution would involve both approaches."

Over the last decade, much of the focus in the field of driver risk management has shifted onto the role of the driver as the architect of their own risk profile, and the importance of self-evaluation and self-development has been emphasised. For older drivers, their risk profile is situationally skewed by age-related declines, but effective self-regulation strategies can nevertheless mitigate those risks. This report consequently focuses on the risk-increasing factors that affect older drivers; how their interaction with emerging vehicle technology can help to mitigate these risks; and what tools and strategies are available to maximise self-awareness, and thereby support the selection and implementation of timely and effective self-regulation processes.

2. Age-Related Impairment

This chapter focuses on the literature around the relationship between key age-related declines and driving problems, and presents the current position on how to effectively measure these declines, in order to ensure that effective interventions can be implemented to minimise older drivers' risk on the road.

2.1 Background

It is estimated that the proportion of people aged over 60 will almost double globally by 2050, from 11–12% to 21–22% (2, 3), with 12% (one billion people) classified as older adults by 2030 (4). Many authors have noted that the number of licensed drivers falling into the 'older driver' category has already increased significantly in the last 30 years (5–7). The proportion of older drivers is currently highest in developed countries, standing for example at 26.6% in Japan and 14.9% in the USA in 2015 (8). The US National Center for Statistics and Analysis (9) reported a 33% increase between 2006 and 2015, to 40.1 million older drivers.

Road crashes are responsible for a million deaths per year across the world among people over 60 (10). Mortality rates can be twice as high for this group as for younger adults (11). Fatality statistics showed that 17% of road deaths in Canada involved older people (over 65), whereas they accounted for only 14% of the population (12).

People who are entering the older driver category now and in the future expect to continue driving independently (13, 14). Canadian figures indicated 75% of older people hold a driving licence, and 16% of those are over 85 (12). Private cars are likely to remain the preferred transport option for these 'new' older drivers, who will travel more than previous generations of older people (15). This preference will combine with the increases in the older population to significantly increase older drivers' exposure on the road (16, 17).

It is well known that whilst older people have relatively few crashes in absolute terms compared with other age groups, they have the highest risk of serious injury and death in the event of a crash, on account of their frailty (18, 19). Older drivers are less consistent in their driving performance (20), and this is attributed to age-related sensory, cognitive, and physical impairments (15, 18, 19); therefore the crash rate increases substantially after the age of 75 (21), and at-fault casualty crashes are significantly more prevalent among drivers aged 80 and over (22).

The pattern is quite consistent across the developed world. Between 2003 and 2012, Australia saw an increase in the number of older drivers, but crash, serious injury and fatality numbers remained static for 65- to 84-year olds and actually increased for the oldest group (85+), while younger driver numbers also increased but crashes, serious injuries and fatalities amongst them either remained steady or decreased (23). In Queensland specifically, in 2014–15 the 60–74 age group accounted for 17.9% of the licensed population and 6.5% of fatalities, while those aged 75 and over comprised 5.3% of licence holders but accounted for 10.9% of the fatalities (24); moreover, drivers aged 80 years and older were most likely to be at fault in crashes, regardless of the crash severity (22).

Research from the USA (25) using crash data from 1975 to 2008 found reductions in fatal crashes involving older people despite increased exposure, from 18% in 1997–99 to 14–15% in 2006–8, a reduction attributed to the success of road safety initiatives, and a finding that was replicated by other US studies (26–28). A 37% reduction in fatal crashes involving drivers over 70 observed in one US study far exceeded the 23% decrease among the 35–54 age group (26). Greater reductions in the fatality risk for older drivers reflect a reduced crash risk as a result of improved road infrastructure and vehicle technology, and greater survivability owing to medical advances and improved vehicle protection (23).

In the UK there are around 8 million people over 70; 5.3 million of those are over 75, accounting for 8% of the UK population (29). Of UK adults, 74% have a driving licence (30) and the Office for National Statistics estimates that over 9 million people will be aged 75 and over by 2035, accounting for 12.5% of the UK population (29). Research in the UK on fatalities between 1975 to 2010 indicated that despite an increase in the older driver population, their fatality rate has decreased substantially (21). Other research from Great Britain by the Road Safety Foundation (2016) also found that total fatalities, fatalities per licensed driver, and fatalities per distance driven had decreased between 1995 and 2014 for drivers aged 70 (31). As with the US studies, the improvements were attributed to road safety measures, and it was noted that the substantial wealth of experience gathered by drivers who may have been driving for over 50 years would help them to deal with difficulties associated with age-related declines in cognitive, visual and perceptual functioning (21).

The evidence shows that people are driving further, and for longer into their old age, and doing so more safely than ever before; but ultimately there comes a point where many people are unable to drive safely and must therefore make the decision to give up driving. This is one of the hardest decisions for older people (32), as driving is so fundamental to one's sense of independence and freedom, and is in turn intrinsically linked to quality of life (33, 34). Driving has been found to be a key determinant of older people's social engagement and family involvement (12). Driving cessation is linked to negative outcomes such as reduced social interaction, poorer health and depression (35–37).

The difficulty in judging the most appropriate point for giving up driving comes from the need to balance the personal and social benefits of driving against how well he or she can cope with the demands imposed by such a complex task – a balance that will be different for every individual and which will inevitably change over time. The driving task requires strength, co-ordination, flexibility, visual acuity, attention, memory, decision-making and judgement (38), all of which can be affected by age-related declines, thus increasing risk.

2.2 Cognitive impairment

There are well-established concerns pertaining to crash risk in older drivers with poor or declining visual, cognitive and physical function (39, 40). Mild cognitive impairment (MCI) has been a key focus over the last 20 years, and concerns the area of declining cognitive abilities lying somewhere between the normal range and dementia (41); the prevalence of MCI in European countries is estimated to range from 5% to 36% (42). It is important to understand exactly how these declines affect on-road driving, the impact they have on crash risk, and how (or, indeed whether) older drivers are modifying their driving to compensate for the effects of MCI (43). Some of the initial research has painted a somewhat alarming picture about the lack of adaptive strategies and self-regulation among MCI drivers – for example, finding that drivers with cognitive impairment are twice as likely to be involved in at at-fault crash than diabetic drivers, and three times as likely as drivers without either condition (44). However, the relationships identified between impairment and crash risk have been inconsistent between studies; for example, the small number of naturalistic longitudinal studies have indicated equivalent or lower crash risk for drivers with cognitive impairment, indicating the presence of adaptive strategies (45).

A recent Australian study found that around 90% of drivers with cognitive impairment reported driving less than 100 km per week, and 67% reported that their average distance driven was less than 5 km per journey (46); while a French study concluded that self-reported cognitive difficulties were the best predictors of driver avoidance, surpassing as an indicator even speeding, failing to give way and braking too quickly (47). In the USA, research indicated that driving difficulty increased at a greater rate for drivers with MCI, and that they reported reducing their frequency of driving in challenging situations (48). Drivers with MCI have also been found to report greater discomfort while driving, and to avoid driving at night, or on motorways, or in unfamiliar areas –this being linked to awareness of declines in ability among those who have problems with night vision, memory and cognitive processing (49). The evidence suggests that self-awareness of functional decline may encourage adaptive behaviour in drivers with MCI, particularly in situations that they find more demanding (46).

Whilst high levels of driving experience are associated with greater situational awareness, declines in cognition may have a negative effect on situational awareness and processing speed (50). This concept has not been widely investigated in the literature to date (17), but studies show poorer situational awareness in drivers aged over 65 years than in those in the 18–25 age group (51), and it has been suggested that this is linked to declines in cognitive, sensory, and motor functioning (50, 52). It has been hypothesised (53: 2) that:

> "a 'U' shaped curve may exist whereby young drivers display lower situational awareness compared to mature drivers, and senior drivers decline in situation awareness when experience is no longer able to compensate for neurodegeneration."

Studies focusing on the specific aspects of cognition associated with crash risk among older drivers have found strong associations between visual attention, executive function and risk (54, 55). A study of MCI drivers has revealed significant error rates and delays in comprehending phonological information, indicating that these are early signs of deterioration which can be detected when drivers are still active and no major on-road deterioration is apparent (42). The authors concluded that deterioration might become evident when it is necessary to communicate behavioural intention while preparing for a manoeuvre, for example when approaching a turn across opposing traffic – a situation which represents one of the greatest risks for older drivers, who are constantly over-represented in angle collisions, crashes at intersections, turning, and changing lanes (56, 57). When turning, older drivers focused on their own turning behaviour and the structure of the roadway, while middle-aged drivers focused on the changing behaviours of other road users ahead of them in the traffic, suggesting that older drivers prioritise their attention differently during turn manoeuvres, something that may be a product of cognitive differences (53).

In addition to difficulties making turns across the flow of traffic, MCI has been linked with difficulty maintaining speed within the speed limit, failure to respond to stop signs, failure to monitor traffic, and difficulties maintaining lane positioning (46), and slower reaction times may lead older drivers to need to brake heavily (58). However, studies have indicated that older drivers with lower baseline function were less likely to be involved in speeding events (59), which is consistent with previous findings suggesting that they display more caution, self-restriction or avoidance with increasing age (60, 61).

Understanding the cognitive characteristics associated with older driver risk has important implications for safe mobility in older adults, as it can inform educational efforts to mitigate the risks of age-related cognitive declines (62). Driving assessments focused on the factors that differentiate higher- from lower-risk drivers would enable targeted intervention strategies to be employed so as to enhance driving competencies and reduce risk (63).

2.2.1 Assessing cognitive impairment

Currently no single cognitive test has demonstrated the ability to distinguish safe older drivers from unsafe ones; with this in mind, it should be noted that caution is required when attempting to use cognitive tools to predict older driver risk (63–65), as research using cognitive predictors of older driver performance found the proportion of variance explained is both low and variable (66–68). However, other research has also indicated that high-demand driving tasks may be affected early in the onset of cognitive impairment, and corresponding deterioration can be seen in assessments of executive control, so it may be possible to use these as a pre-assessment, albeit not as a sole measure (42) of decline.

Cognitive tests have been used in attempts to assess older driver capability for a number of years; one such is the Trail Making Test, a measure of general cognitive function and executive functioning involving a timed task in which the participant must search for and connect letters and numbers in a sequential order. A time of more than 180 seconds has been reported to indicate increased crash risk (69), but evidence of deterioration has been found in drivers with times exceeding 120 seconds (70). Other measures include the Montreal Cognitive Assessment (MoCA), in which scores of less than 26 out of 30 suggest MCI (71). Selective attention (UFOV 3), spatial ability (Block Design) and executive function (D-KEFS TMT 5) have been established as optimal measures of visual–motor co-ordination (VMC) (72).

There appears to be a deficit in research directly linking performance on cognitive tests with actual on-road risk outcomes. It is likely that the associations are not clear-cut owing to the huge number of other variables affecting older driver risk, not least variations in self-awareness and corresponding adaptive behaviours. However, some measures are more well established than others in the literature as valid measures of older driver capability, particularly the Useful Field of View (UFOV) test, discussed in section 2.2.2.

Simulated driving offers an opportunity to overcome some of the challenges involved in linking tests that are not directly related to the driving task with on-road performance, and recent studies have shown strong correlations between simulated driving and on-road driving performance of older drivers who have reduced functional and driving abilities (5). This will be discussed further in Chapter 4.

2.2.2 Useful Field Of View

The UFOV test was developed to measure age-related changes in the functional visual field that could not be identified or measured by means of standard ophthalmic tests; it is best described, though, as a measure of efficient processing of visual information (73), and it is widely recognised as a good predictor of older drivers' on-road performance (74).

The UFOV is the area of visual focus observed without head or eye movement. The smaller the UFOV, the lower the driver's capacity to observe safety-critical hazards emerging from the periphery of his or her vision (75). Visual search efficiency declines with age, particularly in terms of (a) ability to divide attention between the central focus and the periphery, (b) preventing a return to already searched locations in favour of unsearched ones (inhibition of return), and (c) switching attention between tasks in a timely manner – all of which are critical to the driving task (76). Older drivers with declines in UFOV were found to be twice as likely to cause crashes over five years, even when they were aware of the declines and consequently implemented self-regulatory behaviours (77).

UFOV impairment has also been found to be reliably associated with difficulties in estimating time to collision, so among highly impaired drivers, even when a hazard is observed, it is not processed effectively in terms of threat evaluation (75). Attentional deficits measured by UFOV tests are also associated with difficulties maintaining lane positioning (63), lane change errors and failing to stop at red lights (78). These difficulties can be exacerbated by the effect of the traffic environment at the time, such as perceived pressure from other drivers to make a manoeuvre in a timely manner (79); this means that driver assistance systems may be useful in reducing the demand on the driver and thus preventing further inflation of the risk-increasing effects of UFOV declines (75).

2.3 Workload

The impact of the increased workload that is placed on older drivers by challenging driving situations has been established as being measurable by changes to their eye movements and their visual scanning capacity (80), which has been attributed to a requirement for more effort to support performance to compensate for cognitive declines. Older people disengage from tasks at lower difficulty levels than younger people, and they require more effort to perform cognitively demanding tasks, but the amount of effort they put in is determined more by their *perception* of the difficulty of the task and of their ability to meet its demands, than by the *actual* difficulty of the task (81).

Junctions are a key focus of the older driver literature, owing to the prevalence of at-fault intersection collisions, which is attributed to attentional demands arising from complexity of environment, time pressure, and increased mental workload (75). In the USA in 2016, 37% of all fatal crashes involving drivers over 65 were intersection incidents, compared with 20% for crashes in which no driver was over 65. According to US research, particularly high-risk manoeuvres are: turning across opposing traffic, merging from a slip road, and changing lanes on a highway (82); this is a consequence of the complexity of perceptual and cognitive processes involved in gap selection and acceptance processes, and the requirement of older drivers for longer time for perception–reaction (83).

Driving at peak times of day has been reported as increasing at-fault crash risk in older drivers by over 40%, owing to the demands imposed by higher traffic volumes and more frequent and faster interactions seen at such times, all of which exacerbate cognitive workload and worsen task-induced fatigue (83).

There is evidence that older drivers subconsciously engage in enhanced stereotyping as a strategy for reducing cognitive workload, as stereotypes are a type of well-established schemata stored in long-term memory which provide a mental shortcut to evaluating a situation; but this stereotyping can cause higher levels of bias in people with greater cognitive decline, which can in turn lead to perceptual errors (84). Older people can overcome the effects of bias arising from particular stereotypes, but they require more effort to do so (85), thus negating the benefits that using stereotypes may offer.

Increases in cognitive workload have been associated with slow cognitive processing and delayed response times, and this increases crash risk, particularly when workload is increased by distractions that are not directly related to the driving task; older drivers who experience declines in processing speed in a situation that divides their attention are thus more susceptible to distraction-related crashes (86).

Older drivers have also been found to be most susceptible (of all age groups) to in-vehicle distractions, such as mobile phones, passengers, eating and drinking and smoking (87), although they were relatively unlikely to actually use electronic devices when driving – this, however, may be attributable to generational differences, so an increase in older drivers' engaging with electronics while driving might be observed in forthcoming years (88). Interaction with pets was one of the three most commonly reported contributors to crashes or near misses, and a positive but non-significant association was found between driving with pets and crashes (after adjusting for age of driver) (86).

2.4 Dementia

Dementia refers to a group of diseases in which nerve cells in the brain die or no longer function normally (89). Cognitive function exists on a continuum, ranging from normal functioning to severe dementia, with points at which mild and severe dementia can be diagnosed. Alzheimer's disease (AD) is the most common type of dementia, with US statistics indicating that one in nine people over 65 suffer with the condition – a proportion which increases with age (9).

Complex tasks – for example when dealing with navigation instructions or complex junctions – have a particularly strong effect on AD drivers: they fail to adapt their decision-making strategies to the situation in hand, leading to higher frequencies of random decisions (90). When compared with younger and healthy older drivers, AD patients showed poorer performance in making turns across the flow of traffic, but the deficits were much more marked in complex junction situations than in simple ones (91).

Studies have indicated that drivers with dementia are cognitively slower than healthy older people (91), and they are between two-and-a-half and five times more likely to be involved in a collision as drivers without dementia (92, 93), which raises questions concerning ways to evaluate the point at which drivers should no longer be permitted to drive, and how to identify areas in which risk-mitigation measures can be employed to support them in their desire to continue driving safely for as long as possible. Research has investigated the extent to which dementia screening measures can be used to assess driving abilities, but these tests have limited validity and sensitivity in the driving context, and therefore do not discriminate adequately to be a useful indicator of on-road risk (94).

Some studies have indicated that people diagnosed with dementia actually have a lower crash risk than other older drivers, which has been explained in terms of either self-regulatory behaviour or regulation imposed by carers after diagnosis, resulting in changes in driving choices – including decreased driving exposure[1] – which offset the risks associated with cognitive declines (45). A study comparing AD patients with age-matched controls reported 45% lower self-reported weekly mileage in the AD group (95), although of course inaccuracies in self-reported mileage may be particularly strong among AD patients (96).

2.5 Visual problems

Static visual acuity, contrast sensitivity and the extent of visual fields all decline with age, and may all affect driving abilities (96). Ophthalmic tests can be used to measure the extent of deterioration and thus corresponding risk, for example scores of 1.25 or less on the Pelli-Robson chart for contrast sensitivity (97) have been found to represent severe deficits which may be indicative of increased crash risk (98).

Recent Australian research reported that declining contrast sensitivity and lower driving confidence were both associated with higher frequencies of rapid deceleration events in older drivers, and concluded that deficits in visual function can affect driving safety (58), which is consistent with earlier findings linking declines in contrast sensitivity to crash risk. This finding is in agreement with other research that has found associations between poor contrast sensitivity and increased crash risk (98, 99).

With every 13 years that passes from the age of 20, drivers require twice as much light to drive safely, so a 72-year-old needs 16 times as much as a 20-year-old (100) and a 65-year-old's eye may let in just a third as much light as that of a 20-year-old under low-light conditions; in combination with declines in cognitive processes which optimise dark and light adaptation, and higher rates of age-related eye diseases (such as cataracts, glaucoma, diabetic retinopathy and macular degeneration), this poses significant challenges for older drivers (76). These effects can be seen not just when driving in darkness, but also in wet weather conditions, which reduce visibility through rain, spray and dim ambient lighting (83, 101). Age effects on night vision led US researchers to expect a positive correlation between age and use of high-beam headlights, but in fact the oldest drivers were found to report the *lowest* rates of high-beam usage (27%, as compared with 37% for middle-aged and 49% for younger drivers), which was explained in terms of changes in driver education which, in this age of improved headlight technology, no longer focuses on the risks of headlight glare to oncoming vehicles (88).

Drivers with lower visual function drive fewer miles than those with higher visual function (102, 103), and declines in contrast sensitivity seen in over-70s has been linked with driving cessation (104), which may be considered to reveal adaptive strategies in response to age-related declines, although concerns exist about whether lower exposure provokes deterioration of driving skills (58). The extent to which reduced levels of driving hinders the driver's ability to self-monitor progressive deterioration are also unclear.

1 The term 'driving exposure' encompasses an overall assessment of how much driving is being done, and can include total distance travelled, the radius of travel from home, the average trip distance, and how much nighttime driving is done.

2.6 Personality and affect

The personalities and attitudes of older drivers have been widely linked to self-reported risky driving and to crash involvement (105), but the nature of the links is not straightforward, as not all aspects of driving are influenced by personality factors in the same way (106). One study identified an association between sensation-seeking and risky driving in older drivers, using a driving simulator (107). Most research in this area has focused on the Five-Factor Model (108), with Extraversion linked to poorer on-road driving performance in older drivers (106), and in other studies to continuation of driving (109); the weakness of the associations suggest that whilst a relationship between Extraversion and driving self-regulation among older drivers does exist, demographic, psychosocial and cognitive measures may have substantially more influence (110). The Reinforcement Sensitivity Theory model of personality (111) finds its basis in neuroscience, and focuses on the existence of two distinct neurological systems: one controlling avoidance behaviours (the Behavioural Inhibition System) and the other approach behaviours (the Behavioural Activation System (BAS)), which determine 'reinforcement sensitivity' – the magnitude of the effect of reward and punishment on behaviour. The relationship between reinforcement sensitivity and self-reported driving indicates that personality differences do affect older drivers' self-assessment, and in turn their self-regulation and cessation processes (5).

Whilst emotions and emotional distress do not directly affect driving performance, they compete for the cognitive resources needed for safe driving, and compromise decision-making capabilities (112). The relationships between self-reported emotion and subjective driving performance in older adults has been examined, and greater emotional distress was found to be related to aberrant driving behaviours (113).

Driving anxiety is commonplace among older people, with studies indicating that 17–20% are affected (114), and driving anxiety is widely cited as a reason for driving cessation, to the point that it is linked to over-zealous self-regulation, unnecessarily restricting driving (115). Simulator studies have found that anxious drivers suffer greater performance impairments as task demand increases (116), and this is consistent with findings from studies that rely on self-report behaviours (117, 118).

There has been little research investigating the relationship between other common emotional symptoms (i.e. aside from anxiety) and driving performance in older people, which has led some researchers to raise questions as to whether other emotional symptoms may be partially responsible for the high crash risk and self-reported driving difficulties often observed in older adults (113, 119). However, there is some evidence that emotional symptoms associated with negative thinking in older adults have been shown to redirect cognitive resources needed for driving to alternative stimuli (113). Studies have found that older people with agoraphobia, social phobia and driving-related anxiety display adaptive behaviours, particularly driving less frequently, using alternative modes of transport, and driving at times they perceive as lower-risk – hence the process of fear avoidance reduces their exposure, and therefore reduces their overall risk (114).

Confidence among older drivers has been shown to vary dramatically, typically reducing with age and functional declines (101), with decreasing confidence noted as a key factor in avoidance of difficult driving situations such as driving at night or in bad weather (120), and ultimately in driving cessation (121). However, subjective discomfort during driving may have a greater impact on driving avoidance than objective self-awareness (122), and self-regulation based on lack of confidence, as opposed to self-awareness, is concerning (94), because drivers with low confidence have been found to be nearly twice as likely to be crash-involved as a result of the adoption of overly cautious driving styles (123). This discomfort can result in unnecessary driving restrictions, whereas they could continue to drive quite safely by adopting effective coping strategies such as journey planning or assistive vehicle modifications (124). Gender differences in perceptions of driving competency and self-regulatory practices have been widely reported (125–127) with older women reporting lower driving confidence, more willingness to accept changes in their driving habits, and more likelihood of voluntarily reducing their driving or stopping altogether.

2.7 Self-report

Older drivers, like all drivers, tend to overestimate their driving ability and thereby underestimate their risk. Studies have shown that 85% of older drivers rate themselves as either good or excellent drivers, regardless of their crash or violation history (121). This is likely to introduce bias into the way they self-report both their own behaviour and other variables such as their crash history. Research conducted in the 1990s indicated that there were substantial discrepancies between self-reported collision involvement rates and the rates indicated by official records, but the relationship between the two is not always clear-cut, and variations in findings may be linked to methodological differences.

For example, a US study of 53 older drivers focusing on police-reported accidents over the preceding five years found that 12 out of 18 drivers with recorded incidents did not report them in the study (128), while another looked at 175 drivers with collisions on the official record indicating that the police had attended, in which 64 had a crash in the official record which they did not report in the study (129), leading the authors to conclude that self-report was not an appropriate method for identifying crash-involved drivers. By way of contrast, a more recent study of self-reporting of police-attended collisions indicated substantial agreement between self-reports and official records (130).

Other studies have looked at self-reports compared with crash rates recorded by insurance providers, including one published in 2018 which found that older drivers self-reported almost 31% *more* collisions during the study than appeared on the insurance record (5), a finding consistent with those from earlier studies (131, 132).

This discrepancy may be linked to the extent of the damage related to the collision, or the absence of third parties; or it may be influenced by the risk of increased insurance costs associated with reporting a collision to an insurer even if it does not result in a claim (which might lead a driver to acknowledge an accident to researchers that they concealed from their insurer). These effects were, however, consistent across the older driver group, with no increases seen among the 'oldest old' (133). The authors note that it would be interesting to examine age-related differences in self-reporting of non-claim collisions across all age groups, and they observe that among the few instances whereby collisions on the official record were not reported in the study, confusion over timings, memory or self-presentation issues may be responsible, rather than consciously introduced self-report bias (134).

This raises the question as to whether self-report measures can be relied upon as indicators of older driver risk, and whether reliability depends on the nature of the measure. Reporting of incidents appears to show variation in accuracy, but, as noted above, this may be affected by age-related declines. However, measures focusing on personality and affect, rather than recall, might not be influenced in the same way.

Studies have confirmed that the relationship between self-report driving measures and personality factors applies to older drivers with reduced functional abilities (5), and the discrepancy between self-reported and actual driving has been attributed to the influence of personality factors such as impulsivity on older drivers' self-reporting behaviour (135). A study using on-road driving assessments as an objective measure of driving behaviour did not establish any links between self-reported sensation-seeking and driving (106).

The effects of self-report bias are also clear in relation to reports of executive functioning, with studies showing that self-reported executive functioning was correlated with personality, but not to objective measures of executive functioning, suggesting that personality factors affect self-reporting accuracy in older drivers – for example, those high in Conscientiousness might have higher self-awareness and produce more negative self-report assessments, while drivers high in Neuroticism are also likely to be more negative in their self-assessments (136). Equally, sensitivity to reward and punishment may affect self-report behaviour, as drivers with high reinforcement sensitivity may be unwilling to report incidents (5).

An inability to make accurate self-assessments can not only impact the results of self-report measures, but also impede the development of appropriate self-regulation behaviour, since self-awareness is critical in the process of making judgements about the requirement for adjustments, and making relevant decisions about what those changes should be. The benefits of driving into older age are well documented, as are the negative effects of restriction and cessation of driving, including social isolation and depression (137). Self-regulation is often perceived as synonymous with driving cessation, but in actual fact appropriate modification of driving habits in response to declines in functional abilities is the core of successful self-regulation (138). Studies have shown that older drivers often self-regulate spontaneously, with some studies reporting that the extent of age-related functional declines are associated with reduced mileage (102), and others finding effects for just age (59). These changes are attributed to lifestyle changes as well as age-related functional changes (43). The tendency to self-regulate driving is influenced by factors including personal interests, improving or maintaining self-esteem, and self-definition (139), which may introduce self-assessment bias – which may, in turn, influence self-regulation and driving cessation (5).

In addition, older drivers' self-regulation behaviour creates exposure patterns which are different from the overall driving population. In the USA in 2012, older drivers were 75% more likely than younger drivers to be involved in a two-vehicle crash between 14.00 and 18.00

and during daylight (140), which was attributed to their preference for driving during the day (141). Drivers aged 80 and over have been found to avoid driving in bad weather, on busy roads, and on unfamiliar roads to a greater extent than younger drivers, and even to a greater extent than those in the 75–79 age group (142). Moreover, older drivers use motorway-type roads significantly less often than younger drivers, and avoid right turns while driving on the left (and left turns when driving on the right), although their increasing reliance on navigational assistance technology may be reducing their tendency to seek alternative routes to avoid such traffic situations (87). US statistics indicate left-turn crashes (i.e. turning across the flow of traffic) were substantially elevated among older drivers, an effect that increased with advancing age within the older driver group (140), whereas their representation in crashes that involved driving straight, passing and overtaking was no different to that of other age groups – a finding attributed to their self-regulation, and to avoidance of manoeuvres that they perceived as higher risk or that could reasonably be avoided (143).

Despite the prevalence of self-regulation, it is clear that a proportion of older drivers do not self-regulate, even in the face of age-related declines, something that has been attributed in part to diseases and cognitive declines themselves interfering with the ability to self-assess (61) – although studies on self-reported driving indicate that dementia sufferers tend to follow guidelines on limiting or giving up driving (45). Self-regulation will be discussed in more detail later in this report.

2.8 Measures

2.8.1 Telemetry

Given the challenges associated with self-reports of factors indicative of older driver behaviour and risk, it is possible that more-objective measures may provide valuable insights into the actual driving performance of older drivers. Advances in the sophistication and availability of in-vehicle telematics systems mean that they may now offer an easily implemented and low-cost way of identifying risk patterns in the driving profiles of older people, which can be used to steer appropriate education and regulation – and, ultimately, cessation. In recent years, studies have been conducted utilising these technologies to gain insight into older driver risk and avoid the subjective influence of self-reports, or the ecological validity problems associated with simulator studies (87).

2.8.1.1 G-force

Acceleration and deceleration behaviour has been found to be a more accurate predictor of crash involvement in bus drivers than speeding, particularly for at-fault crashes (144, 145). Naturalistic driving studies have linked rapid evasive driving manoeuvres, particularly braking responses, to near misses (146, 147).

Much of the telematics research has used G-force data as the key measure of driving behaviour, and the majority of systems record an ‘event’ when a predetermined G-force threshold is breached. The challenge lies in setting these thresholds appropriately, so that they are sufficiently sensitive to detect risky behaviours, but not so sensitive that the events become ‘noise’. The US 100-Car Study developed algorithms using G-force measures in conjunction with dashcam video footage, and found that those involved in crashes and near misses decelerated at in excess of 0.3 G more frequently than uninvolved or rarely involved drivers (148), while others have set thresholds as low as 0.15 G (146). A similar process has been undertaken by the Strategic Highway Research Program 2 focusing on steering, deceleration and acceleration (145). A deceleration rate of 0.49 G has been described thus (149: 2):

> “…the driver would feel like they were thrown forward towards the steering wheel and the load in the vehicle would shift to the front of the vehicle. Objects placed on the seat unrestrained would probably be thrown to the floor.”

A deceleration of 0.75 G slows a vehicle by 16.5 mph each second, so would bring a car from 33 mph to stationary in two seconds, while a front-end collision is likely to measure several G (58).

The 100-Car Study data reported that events exceeding 0.7 G were infrequent, but were more frequent among drivers categorised as ‘unsafe’ on other measures; this suggests that events breaching high thresholds represent more extreme behaviours and therefore may be a more valid proxy measure of crash risk than events breaching thresholds set at more moderate levels (149), which is consistent with conclusions drawn by other researchers (58, 150). However, there is some ambiguity in the findings relating to telematics data. For example, one study focused on deceleration events exceeding 0.35 G over the course of a week, using a sample of 1,425 drivers aged 67 to 87 years (151). Drivers with lower mileage had higher rates of events, but also better vision and cognition – a finding that might be explicable could be explained in terms of thresholds, sample sizes or monitoring periods, but which suggests that further study of deceleration event patterns in older drivers may be required (58).

Many telematics systems provide high volumes of data, but this data needs to be processed appropriately in order to detect true events. The 100-Car Study used data collected at around 32 points per second; because of this high frequency, no further events were recorded within three seconds of an event threshold being breached, in order to avoid the frequency of false-positive events being recorded (152).

2.8.1.2 Speed

Speed is a key measure that can be gathered from telematics systems and then analysed to contribute to understanding of older driver risk, although it has been noted that there is a lack of research evidence explaining the relationship between speeding and self-regulation (153). A study analysing a week of driving data from older drivers reported that cognitive and visual function, driving behaviour and attitudes were not predictive of speeding events by distance driven (154). A randomised control trial evaluating the effectiveness of an education programme for older drivers in Australia gathered data from a cohort of drivers aged over 75 (with a median age of 80 years) across a 12-month period, and found that speeding behaviour was highly common, with almost all participants involved in speeding events (59), which is consistent with previous research using naturalistic driving measures (155, 156).

Despite the frequency of speeding being high, the magnitude by which the limit is exceeded tends to be low, with most events involving low-level speeding of between 1 km/h and 9 km/h over the speed limit (59). Older drivers report making an effort to comply with speed limits, and say that speeding is most often due to an involuntary error, which is consistent with findings relating to other common traffic violations such as going through traffic lights that are in the process of changing to red, or not actually stopping at a stop sign (157). A French study showed that speed limit compliance is a particular area of focus for older drivers, owing to the stringency of speeding enforcement in France; this means that they are highly aware of the risk of unintentional speeding affecting their licence status, and, consequently, their mobility. Factors identified as exacerbating task difficulty were unfamiliarity of route, and frequent changes of speed limit, as these mean they have to exert more effort in attending to the driving task in order to avoid unintentional speeding, which impacts on task performance (157). Despite a general perception (and some research evidence which backs it up) that older drivers are predisposed to driving slowly, some studies have not found any support for this relationship; indeed, some have found that older drivers travel faster than younger drivers on certain road types, but the unintentional nature of the violation means that encouraging older drivers to pay more attention to their driving speed may reduce the frequency of their speeding incidents (87).

2.8.1.3 Lane position

Measures of lateral lane positioning may also be indicative of driver impairment (158), as studies have shown that older drivers experience difficulties in lane (position) maintenance under challenging driving conditions (159), although other researchers conclude that there is little evidence of a relationship between cognitive functions and lane maintenance in older drivers (160). Nonetheless it has been argued that lane positioning is more safety-critical than speed for older drivers (161); comprehensive and reliable tracking data can be gathered, which is sensitive to variation in driving performance (162), and which can be analysed using traditional measures of central tendency – such as mean and standard deviation of lane position – in combination with variables such as lane departure counts (163).

2.8.1.4 Gaze tracking

Other types of telemetry have been used in attempts to measure older drivers' on-road risk, particularly combinations of eye-tracking data in combination with GPS location, to quantitatively analyse gaze behaviour at specific on-road locations and situations (164), using real on-road data, in order to draw conclusions about VMC (80). Using VMC as a performance measure can help identify operational deficits in older drivers, and in turn can guide coping strategies and tailored interventions focusing on a given driver's individual capabilities (72).

2.8.2 On-road assessments

Clinical measures have not proven to be a valid predictor of on-road driving behaviour in older drivers (165), so the identification of risky older drivers and their higher-risk behaviours using proxy measures remains a significant challenge (72). On-road assessments are regarded as the gold standard (166, 167), but these require standardisation in order to provide an objective measurement (168, 169). By ensuring that a representative range of traffic conditions is encountered, conditions that present an appropriate level of difficulty to the driver, competence can be evaluated as critical elements of driver behaviour can be observed (170). An observation schedule can be used for standardised reporting; one such is the eDOS (see Table 2.1), developed as part of the Candrive/Ozcandrive study, to record systematic and reliable observations which can provide comparative data both between drivers and over time for an individual driver (17; 171).

Table 2.1: Definitions of errors observed using the eDOS

Driving behaviour	Error	Explanation
Observation of road environment: maintaining awareness of surroundings/environment	No mirror use	Non-use of rear- or side-view mirrors
Signalling: ability to signal intention to negotiate an intersection, lane change, merge and low speed manoeuvre	Inappropriate	Failure to use signal/leaving signal on after negotiating intersection, lane change, merge and low speed manoeuvre/use of incorrect signal
Speed regulation: adhering to posted speed limits, and regulating speed consistent with road/traffic	Too fast Too slow	Over limit or dangerous speed for manoeuvre Too slowly (consistently; sign of overcautiouness)
Gap acceptance: making safe judgements about presence of other vehicles and selecting suitably risk-free point to pull into line of traffic, or cross one more lanes of traffic	Missed opportunity Unsafe gap Failure to yield	Overcautious/missing opportunities Selecting unsafe gap Failing to yield (give right of way)
Road-rules compliance: ability to follow and appropriately respond to road signs, and not cross road markings	Non-compliance light/sun Crossing pavement	Failing to comply with road sign/traffic light Crossing pavement marking to the extent of disturbing other road users
Vehicle/lane positioning: position of vehicle while moving or stopped, in accordance with side lane markings on a motorway	Out of lane Hitting curb Inappropriate following distance	Drifting out of lane (with or without marked lanes) Hitting side curb Driving too close to vehicle in front

Source: Koppel et al. (43)

The researchers in that study noted that the eDOS should be used to best effect on driver-selected routes, which would thereby demonstrate their competency in their day-to-day environments, and that assessment should be carried out in their own vehicle (172). This level of personalisation enables assessment of driving that is representative of individuals' real-world experiences – but, of course, any personalised assessments are inherently non-standardised (173). Using non-standardised tests offers customisation, which improves the ecological validity of the output for the driver in question (174), but reduces comparability between drivers, so whereas for research purposes standardisation is often desirable, for individual development purposes this may not be the case. It has been suggested that composite measures accounting for a range of cognitive abilities may be the strongest predictor of age-related declines in driving performance, as composites are broader and more reliable measures (63). This approach has been demonstrated in the Japanese older-driver licensing system, where after the age of 70 drivers must take part in: a lecture; a battery of driver aptitude tests involving simulator driving, field of vision, kinetic and night vision tests; an on-road driving assessment; a discussion session; and, for drivers over 75, a cognitive screening test. However, research has failed to find overwhelming support for the effectiveness of these measures in reducing at-fault collisions among older drivers (175–177).

3. Stress, Confidence and Technology

This section considers the impact of increasing vehicle technology on older drivers, and the corresponding changes in the relationship between older drivers and the vehicles that they drive.

3.1 Vehicle technology

Although older drivers are over-represented in fatal collision statistics, these rates have been falling, which has been attributed in part to improvements in vehicle design (178). Some changes have reduced drivers' visibility, such as increases in pillar size and rear dashboard height in newer vehicles (179), but for the most part the benefits appear to be outweighing the disadvantages. There is little more that can be done to improve the structural safety of vehicles, but the major areas where gains can be achieved are to be found in the constantly developing in-vehicle technologies that can assist all drivers, but which may be particularly beneficial for the older population, as they can offset some of the difficulties associated with functional declines (180–182).

Features that are already common in newer vehicles (such as reversing cameras and collision warning systems), and forthcoming technologies (such as increasingly autonomous vehicles), may help mitigate older driver risk (76). An analysis of research on the impact of advanced vehicle technologies (AVTs) on older drivers reported that they can indeed be of assistance, with benefits including avoidance of crashes and a reduction in their severity, as well as improved occupant protection (181).

Vehicle technologies currently cover a wide range of degrees of intervention, from provision of basic information to the ability to take full control of the vehicle. These have been categorised into a number of levels (183), whereby the lowest level (level 0) may involve assisting drivers via advanced driver assistance systems (ADAS), such as adaptive forward lighting systems, night vision systems, in-vehicle navigation systems and lane departure warnings. Level 1 systems can influence longitudinal or lateral control of the vehicle (but not both at the same time), and include systems such as adaptive cruise control and lane assist systems. Level 2 systems can take longitudinal and lateral control of the vehicle simultaneously, and are the first level at which the vehicle is effectively self-driving, although the driver must monitor the situation and prepare to retake control at any time. Level 3, Conditional Driving Automation, covers highly automated vehicles (HAVs), which would be self-driving – or autonomous – vehicles (AVs) which did not require constant readiness to retake control, but would sometimes require human driver input and reassignment of control to the driver. Level 4 systems (High Driving Automation) would initiate a safe mode if the driver was unable to resume control safely and in a timely manner, while level 5 vehicles would be fully self-driving and require no human control at all (184).

3.2 Advanced driver assistance systems – acceptance and usage

This section considers the nature of modern driver assistance systems, and the way in which older drivers are responding to them.

3.2.1 Assistive technologies

AVT can be of particular assistance in aspects of the driving task that older drivers often find difficult, for example identifying objects in blind spots, navigation, assistance in making turns across the flow of traffic, and identifying reduced headway or insufficient gaps for lane changing or overtaking – although all of these warnings and additional information streams may also act as distractions (100). See Table 3.1 for a broad indication of the types of AVTs currently available to older drivers.

Studies have indicated that whilst most older drivers have positive attitudes to ADAS, barriers to their adoption nevertheless exist, particularly regarding their complexity, safety and reliability concerns, and their affordability (138). However, older drivers are willing to engage with new technology, particularly if the benefits are clear (185), so in order to maximise take-up and to capitalise on the potential safety benefits of ADAS, it is important that appropriate training materials are developed, and that campaigns to raise awareness about the functionality, benefits and limitations of in-vehicle technologies are implemented (186).

Table 3.1: Types of advanced vehicle technology by classification, adapted from Transport Canada Classifications

Classification	Type of AVT
Vehicle control	Roll stability control
	Traction control
	Brake assist
	Parking assist
	Adaptive cruise control
Warning and crash mitigation	Blind spot detection
	Forward collision warning and braking
	Lane departure warning
	Lane keeping assistance
	Cross-traffic detection
	Emergency response
Visibility	Advanced forward lighting systems
	Reversing cameras
	Night vision systems
	Pedestrian detection
Other driver assistance	Driver monitoring (including fatigue alert)
	Speed alert
	Tyre pressure monitor
	In-vehicle concierge[2]
	Integrated Bluetooth telephony
	Navigation
	Voice control

Source: Adapted from Government of Canada (187) & Gish et al. (188)

Studies investigating factors which affect the adoption of AVTs among older drivers have found that whilst awareness of AVTs is relatively high, actual experience of using them is fairly low (189), and also that there is a tendency for perceived usefulness ratings to be low, increasing the tendency of older drivers to reject them. However, whilst age-related changes are not a prevalent reason for purchasing vehicles with AVTs, once they had gained experience with them, the older drivers felt that the technologies were helpful when driving, with the highest score of perceived utility (64%) being related to collision warning systems that alert the driver in response to a bad decision or risky behaviour (157).

The LongROAD study (the *Longitudinal Research on Aging Drivers* study by the American Automobile Association) reported AVTs in nearly 60% of older drivers' vehicles, with the

2 An In-vehicle concierge is a system that that can recommend nearby restaurants, filling stations and the like, and in some cases can adjust heating and other aspects of the in-car environment by voice control.

most commonly reported being integrated Bluetooth telephony, reversing/parking assist, navigation, voice control, in-vehicle concierge[2] and blind spot warning (8). The results also indicated that higher levels of income and education were associated with greater incidence of technologies, which can be attributed to the presence of more of technology in more expensive vehicles, and the affordability of extras among the wealthier segment of the older driver group. The same study also reported that over half the AVTs present were always or often used, with the most frequently used cited as blind spot warning, fatigue/drowsy driver alert, and forward collision warning systems; the least used were semi-autonomous parking assist, in-vehicle concierge, voice control, and adaptive cruise control. The authors explain the high use of certain AVTs in terms of the default vehicle settings, as vehicle manufacturers design these kinds of systems to activate automatically. They also point out that AVTs added to the vehicle at additional cost are more likely to be used, particularly on vehicles owned or operated from new, otherwise the older drivers would not have specified them as extras when ordering the vehicle (8).

When it comes to gender difference, men's attitudes to vehicle technologies are most affected by the perceived utility for their own purposes, while women's are more influenced by social influences and perceived usability (190). One study found that five AVTs were found to be more commonly used by men aged over 65 than women (high intensity headlights, navigation systems, adaptive cruise control, reversing/parking assist and rear-view cameras (191)), while the LongROAD study found no differences for navigation, adaptive cruise control, or reversing/parking assist technologies, but detected differences for adaptive headlights, emergency response, in-vehicle concierge, and voice control (8), with male drivers reporting higher usage than female drivers.

Certain AVTs seem to be meeting greater resistance than others, and the reasons for this are not always clear; voice control, which has relatively low usage rates, is one example. One explanation for this outcome is that voice control systems are difficult to learn, although further research is required to understand why, as at face value it should be relatively simple compared to other technologies. As one study notes (182: 37):

> "As the number and complexity of advanced in-vehicle systems continue to grow, there will be a need to make interfacing with these systems as intuitive and simple as possible. [Voice activated control] systems are a promising method for making interactions with in-vehicle… technologies easier and safer."

3.2.2 Perceived benefits of using advanced vehicle technology

Use of AVTs for speed regulation has been found to be more common among men than women, with the percentage uptake being 67% and 27% respectively (157). The main systems used for this purpose are automatic cruise control, speed warning systems from the navigation system, and speed limiters. The perceived utility of these speed control systems was as high as for navigation systems (157).

A recent Canadian study reported that when drivers' driving performance had deteriorated, their perceptions of the utility of AVTs increased, as they were viewed as supplementing visual, motor and cognitive challenges, assisting not only with day-to-day driving situations but also in high-risk driving situations, such as negotiating careless drivers, heavy traffic and pedestrian congestion, road infrastructure. (188). These findings are contrary to previous research specifying lack of usefulness as a key reason for AVT rejection (189), but the authors explain this in terms of differences in interpretative methods (188).

The US LongROAD study indicated that 70% of older drivers felt that AVTs made them safer drivers, particularly in the case of navigation, blind spot warning, lane departure warning, forward collision warning, and reversing/parking assist. Semi-autonomous parking assist and voice control had the lowest perceived safety ratings, which is explained in terms of a tendency to perceive these systems as making driving easier rather than safer per se (8). However, voice control systems in particular have been found to confer significant safety benefits (192), so it would seem that there may be a gap between the *perception* of safety benefits and the *actual* safety benefits of voice control.

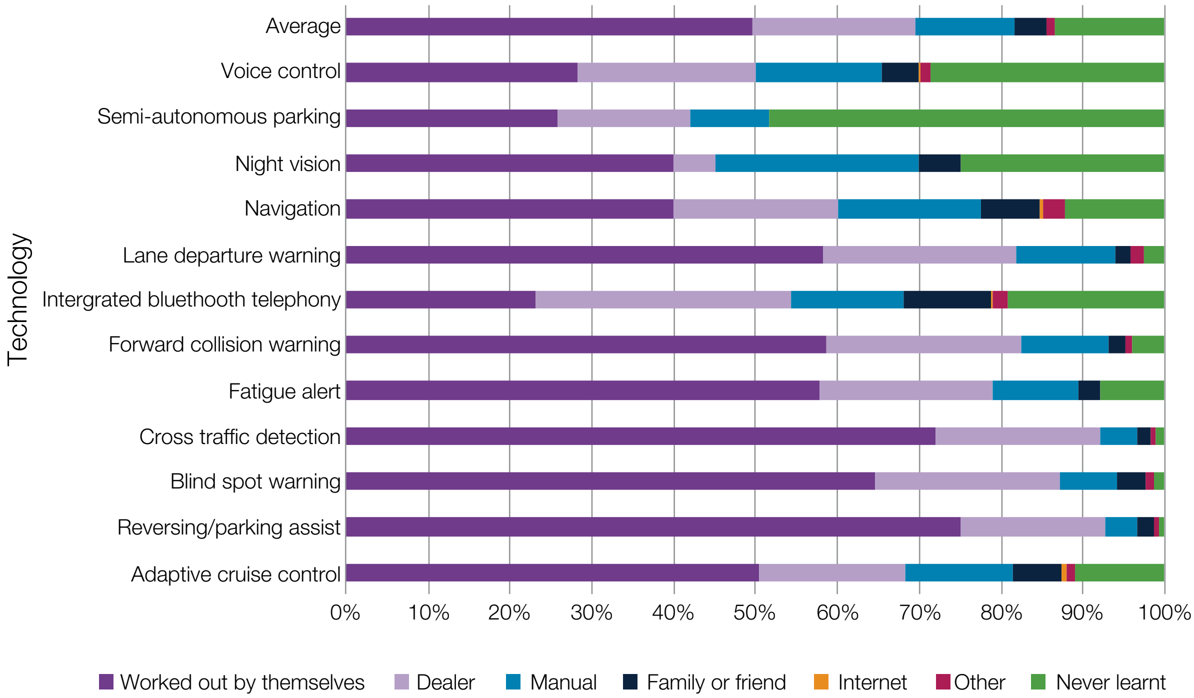
Whilst the evidence indicates that older drivers do perceive the benefits of using AVTs to enhance their driving, and that they generally have trust and confidence in the technological systems, the use of AVTs provokes conflicting ‘automotive emotions’ (193) including feelings of unsettledness, irritation, frustration and aggression, particularly in relation to adaptive cruise control and navigation systems (188). Thus it appears that it is important to educate drivers about the abilities, limitations and availability of assistive technologies, and to help them to acclimatise to the differences in driving with and without the intervention of AVTs, in order to minimise these emotional effects and allow them to benefit from the risk reduction that is associated with effective engagement with these technologies.

3.3 Training in the use of advanced vehicle technology

Older drivers, like younger ones, often learn to use in-vehicle technologies in an unstructured way, but unlike younger drivers, they may not be as technologically experienced, and their cognitive skills are likely to vary to a greater degree (194). Studies have reported, for example, drivers with in-vehicle support systems but with no knowledge of how to use them, and who therefore lacked faith in their capabilities, because the system’s attempts to intervene were regarded by the drivers – based on ill-informed usage – as inappropriate (195).

The LongROAD study (See Figure 3.1) indicated that almost half of older drivers worked out how to use ADAS by themselves, while 20% received instruction from the vehicle dealer; 13% never learnt to use them at all, while a mere 0.1% looked online for guidance (8), with 12% reading the manual to learn how to use them; the remainder (5%) turned for the most part to family or friends (3.9% family/friend and 1.0% other). These findings are in accordance with previous studies reporting that up to 30% of drivers were not aware that their vehicle offered certain AVTs, and so were unlikely to have received any instruction on using those technologies (196, 197). A review by the AAA (American Automobile Association) Foundation for Traffic Safety (198) also reported that half of older drivers learnt to operate their AVTs through trial and error, while 75% used the owner’s manual and 60% received instruction from the dealer (the responses in this case allowing for more than one category of learning method per individual).

Figure 3.1: Proportion of older drivers reporting different methods of learning AVT functionality and use, from LongROAD study data



Source: Eby et al. (8)

If older drivers lack comprehension of AVT function and operation but believe all the same that these technologies will help to mitigate their on-road risk, then targeted training and education are required to fill the knowledge gap in terms of operating the systems and gaining understanding of what they can and cannot do to assist (181, 199). Training opportunities present themselves at the point of purchase and during licence renewal, but currently there is no assignment of responsibility for provision of education and training. Some researchers have indicated that accountability should sit with vehicle dealers (181), whilst others have noted that motoring organisations, such as the AAA in the USA (188), may be well placed to offer training on AVTs to older drivers. In the UK there are organisations that may be in a particularly strong position to promote this education, such as the Guild of Experienced Motorists, Brake (the road safety charity), or even non-motoring-specific entities such as Age UK.

Another underutilised approach relates to online education of the kind that can provide additional information and promote other available resources, for example educational publications such as *Smart Features for Older Drivers* (200) and *MyCarDoesWhat.org* (201). It has been suggested that promotion of online education for older drivers may even assist in reducing the differences in the extent to which older and younger people use the Internet for health and well-being purposes (202, 203). Another suggested approach to improving older drivers' ability to learn to interact with ADAS is to provide intuitive systems that do not require substantial training (204, 8).

3.4 Reversing cameras

Reversing cameras have demonstrated benefits in reducing reversing collisions (205, 206), and since 2018 there has been a requirement for them to be fitted to all new light vehicles sold in the USA (207). Reductions in flexibility, and therefore range of movement, are commonplace among older people, and these restrictions inevitably make reversing manoeuvres more difficult, owing to that fact that it is harder for them to turn round to make 360 degree observations (208). Older drivers have been found to favour ‘pull-through’ parking when possible in order to avoid the need for reversing manoeuvres; nevertheless, reversing is recognised as a common element of day-to-day driving, although older drivers have been observed to favour ‘drive in and reverse out’ strategies more commonly than reversing in, which has been explained in terms of the greater manoeuvring difficulty involved in reversing into a confined space as compared to reversing out of one (179).

Studies have shown that older drivers often do not turn to look behind them when reversing, even when reminded, but this was driven more by habit than physical restriction, with some stating that they considered it unnecessary as they would use the mirrors, a response which was attributed to the nature of driver education at the time when the current older driver cohort learnt to drive (209). Further research indicates that the presence of reversing cameras does not have an effect on whether older drivers turn to look behind them; this may appear to be indicative of risky behaviour, but because structural design changes mean that rearward visibility is decreasing in many modern vehicles, turning to look directly behind when reversing may no longer be the optimal action – although it must in that case be replaced with monitoring the reversing camera screen, which this essentially becomes another window (179). Most older drivers report increased confidence from the greater awareness of the position of their vehicle relative to surrounding hazards that these cameras give, and recognise that reversing cameras reduce the stress of reversing (179).

In order for reversing cameras to be effective, their use must be assimilated into older drivers’ reversing habits, and their existing habits are likely to be well entrenched. In a task involving detecting unexpected hazards, glancing at the reversing camera screen led to lower collision rates, but the frequency of glances decreased over time, particularly in familiar environments with lower perceived risk, such as their own driveways – a finding attributed to failure to incorporate glances at the screen into their reversing habits (210). Driveways and car parks are particular hotspots for reversing incidents (211), so more education may be required to calibrate older drivers’ perceptions of the locations and situations that present the highest risk. It has been hypothesised that the longer a driver owns a vehicle equipped with reversing cameras, the greater the likelihood of regular system usage, but no evidence of this relationship has emerged (180).

3.5 Navigation and route guidance

Age related declines in functioning result in more difficulty navigating, because declines in cognitive, perceptual and motor skills affect development and recall of spatial environments (212, 213), but navigation systems can simplify the driving task by providing step-by-step route instructions, something that is particularly beneficial for reducing cognitive workload in unfamiliar environments (214), although a lack of familiarity with the technology may result in conflicting demands for attention between safe driving and following instructions, thus increasing cognitive workload (215).

A survey published in 2014 of 534 drivers aged 65 and over found that 60% experienced the need for navigational assistance, resulting in use of maps while driving (62%) and reading maps at the roadside (55%), and in some cases writing or drawing their own route plan before embarking on the journey (33%); only 10%, however, reported using an in-vehicle navigation system (214), although this proportion may have increased since the study was carried out as technology becomes more embedded in day-to-day life, and as a new cohort of more technologically receptive older drivers arrives.

An interview study of older drivers in Canada found that they were concerned about the risk of driver distraction presented by navigation systems (216), which is consistent with findings from Australia in which 47% of older drivers rated them as “too distracting” and 35% “too complicated”, while 49% felt that they would cause them to “take [their] eyes off the road for too long” (214). More recent Canadian research reported that most older drivers tend to be satisfied with the clarity and usability of navigation technology, but that drivers who believed that navigation systems negatively affected driving performance displayed poorer on-road driving (215) anyway, suggesting that it may either be a self-fulfilling prophecy or an indication that low technological confidence is prevalent among less-able drivers. The on-road evaluation component found no differences in error rates between drivers who were following navigational guidance and those who were not (217).

Most in-vehicle navigation systems show the driver’s current location on a map-based visual display, alongside the distance to the next turn and the estimated arrival time at the destination. Instructions are issued based on real-time positioning of the vehicle relative to the route, so drivers do not need to retain information in working memory, although the quantity of information presented on the screen can be demanding for older drivers (218). A simulator study reported that older drivers focused on the screen for 0.98 seconds per glance, compared with 0.84 seconds for younger drivers (219), while on-road research findings averaged 1.08 seconds for older drivers and 0.83 seconds for the younger group (220). These findings suggest that older drivers are more visually distracted by navigation system screens, but the benefits the systems provide in terms of reduced navigational workload and increased confidence may nevertheless outweigh the corresponding risks. Most systems also provide audio-based instruction, which has been found to be essential for safe and effective route guidance (221), particularly for older drivers, for whom audible instructions are favourable owing to the fact that they impose lower visual and cognitive demand on the driver (222). Drivers with mild AD used a navigation system providing instructions by visual, audio or combined delivery, and results showed that audio instructions, without visual display, most effectively facilitated navigation (223).

Navigation systems can also provide audible warnings of upcoming speed limit changes and could present images of forthcoming road signs on the display, offering greater advance warning of hazards, a facility that would require a combination of audio and icon-based visual display (218). In France, most navigation systems incorporate speed limit warning systems owing to the stringency of speed enforcement, and a study there has shown that not only is the ownership rate of navigation systems among older drivers very high (70%), but also that they use their systems frequently – not just for route guidance on unfamiliar roads, but also on familiar roads to assist with speed control (156).

Landmark-based route guidance may be particularly beneficial for older drivers, since good-quality landmarks have been found to enhance navigational performance, driving performance and confidence in drivers of all ages, whilst distance-to-turn information resulted in increases in glance frequency and duration, leading the authors to conclude that navigation systems should use distance-to-turn information only in the absence of adequate landmarks for guidance (224). The study showed that landmark-based guidance does not affect older drivers' visual behaviour when presented using a combination of audio and visual methods, but using visual-only presentation led to an error rate six times higher than combined presentation. It has also been suggested that using "street view" images may be useful for older drivers' navigation, presented with point-of-interest information (218), to enable visual referencing.

Good-quality landmarks are defined as having permanence, visibility, usefulness of location (whether the landmark is located close to navigational decision points), uniqueness, and brevity (the number of terms/words used to refer it) (225); thus, a list of UK-centric landmarks proven effective for navigation was developed: traffic lights, Pelican crossings, bridges over the road, humpbacked bridges, petrol stations, monuments, superstores, street name signs, railway stations, and churches (226).

Whilst active route guidance can minimise the cognitive load placed on the driver by providing step-by-step instructions throughout the drive, pre-trip planning may help to increase older drivers' confidence on unfamiliar routes. If the navigational process began with more comprehensive pre-trip planning, more detail could be gathered about a planned route, including road types, junction types, landmarks, decision points and virtual route driving, and there would also be greater flexibility to consider different routes and make a decision between them without time pressure. Being able to convert the output of a pre-trip planning process into route guidance programming would enable the selected route plan to be presented to the driver in real time. Greater flexibility of route planning is particularly important for older drivers, as they are more likely to travel for leisure, implying that choosing a route based on factors other than fastest or shortest should be facilitated (218).

3.6 Highly automated vehicles

It is generally accepted that widespread adoption of autonomous (self-driving) vehicles is some way off, primarily because of uncertainties relating to the early stage of testing of AVs in on-road conditions, lack of clarity about the nature of human interactions with AVs, and the risks associated with overreliance on self-driving technology (100); moreover, older drivers may adopt this technology more slowly than younger people (184). It is clear, however, that during the introduction of self-driving vehicle technology, the human operator will play an active and safety-critical role (217), as the vehicles will sit at levels 2 and 3 of the National Highway Traffic Safety Administration (NHTSA) automation scale (140) – see Table 3.2.

Table 3.2: Definitions of level 2 and 3 automation (NHTSA)

Level 2	An automated system on the vehicle can perform some aspects of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
Level 3	An automated system can both perform some aspects of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.

Source: NHTSA (140)

Despite the fact that widespread use AVs is still a long way in the future, many vehicles already have features associated with self-driving technology, such as adaptive cruise control, intelligent headlights, reversing and parking assistance, blind spot warning, forward collision and lane departure warning systems (100), and these individual technologies have been found in 60% of US older drivers' vehicles (8), suggesting that even the older driver population are in the early stages of engagement with high levels of vehicle automation.

Some studies suggest an inverse relationship between age and acceptance of AVs, partly as a result of age differences in acceptable safety levels for vehicle technology. Older drivers have to perceive a technology as twice as safe as younger drivers in order to accept it, so AVs targeting older people must be designed to be – and be seen to be – safer (207). Age differences in acceptable risk are attributed to differences in risk-taking and sensation-seeking tendencies, which are known to decrease with age (227). Differences in perceptions of a technology also influence decisions about acceptable risk – for example, low trust (228) or high negative affect (229) reduce the likelihood of acceptance.

Despite relatively low acceptance levels for AVs among the older driver cohort, studies have indicated that the majority of older drivers are interested in the idea of higher levels of vehicle automation, and considered that it could improve mobility for older people, particularly when age-related impairments compromise driving capabilities (157). The authors noted that the older drivers' interest in automated vehicles was confirmed by 70% of the sample agreeing to take part in experiments on using HAVs.

A key concern on the subject of the acclimatisation to HAVs relates to the way in which non-driving-related activities affect drivers' ability to take back control from the vehicle when required. A simulator study found that older and younger drivers both engaged in non-driving activities during automated driving, but the younger group (aged 18 to 35) tended to use electronic devices while the older group (aged 62–81) engaged in conversation (230). Non-driving activities did not significantly affect takeover performance, although older drivers who engaged in them displayed more instances of harsh braking than older drivers who did not (217).

Automated vehicle systems are not able to process all possible situations on the road, and when a situation is encountered that does not meet the criteria for automated processing, the driver must retake control, at which point the vehicle initiates a takeover request (TOR) and allows a specified period of time for control to be taken back by the driver, meaning that the driver must stop performing any non-driving-related task and take manual control of the vehicle (231). Current studies of HAVs and older drivers focus heavily on their performance during the takeover process (137, 232–234). Simulator research has not revealed age-related differences in takeover *performance* (232, 233), although differences in *behaviour* have been noted, with safer and more cautious behaviour observed in older drivers (230, 235). These differences emphasise the importance of considering older drivers' requirements in HAV system design.

Current research tends to use 20 seconds as a standard takeover time, which is perceived as adequate and comfortable by older drivers, although in adverse conditions such as fog, a longer time may be helpful – nevertheless, adverse weather has not been found to affect takeover time, although it did have a substantial negative effect on takeover quality (234). They were keen to have a reason for the TOR included in the request, to help provide context to inform the takeover process (184).

A comprehensive study of older drivers' attitudes to HAVs indicated that they are generally positive towards them, as they believe they will assist with their mobility and prolong their independence, by improving their safety and comfort in situations they currently find challenging – driving long distances, on motorways, in bad weather conditions and on unfamiliar roads, to name some Their comfort with an HAV system would be improved if it kept them informed while the self-driving mode was engaged, providing information relating to journey and vehicle status, and traffic conditions (184).

In the same study, a concern was raised about the risk of drivers forgetting that they are in the HAV when immersed in non-driving tasks, and consequently failing to maintain sufficient awareness to effectively retake control, so it was proposed that the HAV system should remind them that they are in an HAV, and notify them when it is adapting its driving to meet the demands of adverse conditions, particularly in relation to adverse weather. Another worry related to the driver falling asleep and failing to respond to a TOR in a timely and effective manner, so the HAV system should monitor drowsiness indicators and warn the driver using an audible alarm and/or vibration should they exhibit signs of sleepiness. They also suggested that it should analyse the drivers' driving style and adapt its own style to be consistent with theirs, whilst correcting all negative elements of the human's driving style; and, taking this idea further, if it identifies risky driving behaviour when it is being driven manually, it should notify the driver in order to assist them to drive more safely (184).

In time, level 3 or 4 HAVs which still allow drivers to take part in manual driving may be more readily adopted by older drivers, whereas a fully self-driving vehicle may be preferable for those who have had to give up driving, as it could help them regain their mobility (184).

3.7 Meeting older drivers' needs

Vehicle technology can reduce older driver risk by compensating for age-related sensory, cognitive and physical declines, and thereby extending safe mobility; however, consideration of both the needs and the capabilities of older drivers in the design of in-vehicle technologies is essential if they are to benefit from the potential risk mitigation that these systems can provide. What is more, their experiences of such technologies may contribute strongly to perceptions among the broader population, as they are likely to be early adopters, because these systems are typically introduced into the higher-end vehicles first (17). It has been noted that a tendency exists for vehicle systems to be designed without sufficient consideration of older drivers' opinions, capacities and needs, which can lead to systems that create more problems for older drivers than they solve (218, 186, 234, 236, 237), as these technologies can benefit older drivers only if their design is congruent with their complex needs and diverse abilities (238).

Three major areas where older drivers have specific needs that could be supported by vehicle technology have been identified as (195):

- divided attention – relationships between cognitive and visual processing tests and driver performance suggest that support in managing on-road situations requiring divided attention would be beneficial;
- look-out – in-vehicle support systems offering observational support in traffic-dense situations and areas in which unexpected hazards are most likely to emerge may bring about safety benefits; and
- continuous situational support – for example navigational guidance, traffic and driving strategic assistance, route planning and speed limit warnings – can reduce cognitive workload and increase confidence, thus reducing errors.

The design of vehicle technology systems is informed by automotive human–machine interface (HMI) design and performance guidelines, which are intended to promote safe design and assessment of in-vehicle systems, particularly with reference to driver workload and distraction. These are 'best practice' guidelines but not mandatory, so they do not offer any regulation per se – instead, they are advisory documents (239). There are numerous sets of guidelines in existence, most notably:

- European Statement of Principles (ESoP) (240)
- Alliance of Automotive Manufacturers Statement of Principles (USA) (241)
- Japanese Automobile Manufacturers Association (JAMA) Guidelines (242)
- Transport Research Laboratory (TRL) Design Guidelines (UK) (243)
- Battelle Crash Warning System (CWS) Interfaces guidelines (USA) (244)
- NHTSA Phase 1 Visual–Manual Driver Distraction Guidelines for In-Vehicle Electronic Devices (USA) (245).

A review of these guidelines identified several areas where they do not effectively address the potential sensory, cognitive and physical limitations of older drivers, probably as a result of incomplete research evidence on which to build detailed HMI design guidance for older drivers, not to mention the absence of legal and policy frameworks covering these areas (186). These types of guidelines tend to be technologically neutral so that they can be applied across different systems (246) and remain applicable over time despite the fast pace of technological progression, but this means that they are often written in such general terms that variations in interpretation are inevitable (186). However, if interpretation is carefully executed and optimal human factors and design principles are integrated from the start of the design process, the chances of older drivers being able to use the end product are increased (17).

The increases in vehicle technology observed in recent years, and those predicted in years to come, present a challenges to older drivers, as it requires them to have the ability to adapt well embedded skills, and also the flexibility to redefine the relationship between the driver and the vehicle. As vehicles become ever more autonomous, it will be increasingly important that older drivers are catered for in the design and implementation process (185). Designing for older people, and developing intuitive and user-friendly systems, would benefit the entire driving population (195). Only by effective collaboration between developers, manufacturers, engineers, researchers, governments and road safety agencies, can automated vehicle technology be implemented to full effect in such a way that it benefits the older driver population (186).

3.8 Advanced vehicle technologies as support for older drivers

There is research evidence for the potential of existing vehicle technologies to assist older drivers in minimising risk and maximising safe mobility and therefore maintaining independence (188, 218, 236, 237). In-vehicle systems can help older drivers to increase self-awareness and understanding of their age-related declines and assist them in mitigating the corresponding risks in an effective manner (236). Developing support systems that can be customised to meet the needs of older drivers is important, as their in-vehicle support needs are slightly different owing to differences in cognition between younger and older drivers (195). Older drivers’ processing speed decreases with increasing cognitive workload (247), which has been linked to age-related limitations in memory and attention and declines in executive function, planning, cognitive flexibility and judgement; therefore older drivers may be more prone to distraction, as they have less attentional capacity and multitasking is more difficult for them (157). In challenging driving situations, particularly where the visual complexity is high, older drivers experience greater attentional demand (248) and carry out elements of the driving task sequentially rather than simultaneously, which slows their processing rate and has been linked to higher crash frequency in simulated driving (249).

Older drivers generally appear to appreciate the safety benefits of vehicle technologies, but it is still unclear exactly which ones are linked to safer driving, and how the effects of the presence of technologies differ under different driving conditions, and for different subgroups of older drivers (188). Some researchers have expressed concerns about whether even lower-level vehicle automation be perceived as providing so much support to drivers that it could lead to overconfidence, which could increase on-road risk and result in drivers continuing to drive for longer than they should (188), which implies that further research into how vehicle technologies affect the timeline of the cessation process is required, in order to build up a true picture of their overall effects on older drivers (115). However, driving anxiety is a problem among many older drivers (as noted in section 2.6), and vehicle technologies can help drivers to feel safer, thus reducing the effects of stress on task performance, and allowing them to dedicate more cognitive resources to hazard monitoring and decision-making on the road with the support of the assistive technologies (188).

4. Effective Interventions

This section considers approaches to ensuring that older drivers receive effective interventions to minimise their risk on the road. It covers ways of assessing older drivers, and the importance of appropriate self-assessment in encouraging self-regulation. It covers the role that family and friends can play in this process, and the difficulties that presents for both parties. The increasing capability of vehicles to provide relevant feedback to the driver is also considered, along with the most appropriate models for older driver risk reduction approaches.

4.1 Assessing older drivers

It has been noted that the concept of the older driver is a construct referenced against the norms of the corresponding time period, and as people are staying active for longer and lifespans are increasing, the definition of an older driver will change – the typical older driver will be even older, and there will be greater representation of female drivers in the population (250). Drivers are already driving more often and for longer into old age; recent research indicates that currently 60% of Australian older drivers are driving more than six times per week, and that overall they have better health than non-drivers (251). Much of the research into older driver assessment has targeted medical fitness to drive, owing to a legislative focus on regulation and licence restriction among most highly motorised nations, but the increases in crash rates among relatively fit, regular drivers who would pass standard fitness-to-drive tests indicates that this approach is not effective for managing risk among the rapidly growing older driver population (252).

This increase in crash risk among relatively healthy, regular older drivers raises three key concerns:

- that older drivers are not sufficiently self-aware to implement effective self-regulation;
- that their self-regulation abilities are insufficient to compensate for declines in driving skills; and
- that their self-regulation behaviour is ineffective and does not reduce crash risk (141).

It is therefore important to determine the most effective ways of assessing older driver risk, to assist older drivers with effective self-regulation, and to allow objective measurement of their driving risk as a backstop for ineffective self-regulation.

Quantifying older driver risk, particularly in terms of evaluating the impact of competing risks, continues to pose a challenge, and some authors have even suggested that traffic researchers have failed to engage with gerontological experts or integrate their general findings into the road safety domain (253). Driver risk research requires interdisciplinary consideration, but if that is insufficient, then research may be – erroneously – grounded in the assumption that older drivers are a homogenous group. This would have the consequence that the effects of substantial individual differences – the positives associated with increased age as well as the negatives – might be ignored (254). Researchers may even go so far as to inadvertently introduce negative bias against older drivers into the research design, because of influences in perception of this group stemming from the media and widely held stereotypes (255), meaning that attempts to assess older drivers may be coming from a negative position by default.

Another perspective on the assessment of older drivers raises the question as to whether they really do need to be assessed differently from other drivers in the first place, for two main reasons: firstly, that individual differences within the older driver group appear to be greater than among younger groups (250, 256, 257); and secondly, because it is possible that problems and errors associated with older driver declines may in fact be normal bad habits acquired and embedded over the years (258). The focus on older-driver-specific assessment has even been attributed to the pursuit of personal gains among traffic researchers, whereby the lure of royalties from the intellectual property associated with older driver assessments may be influencing the direction of the literature, in a way that is reminiscent of the accusations levelled at the pharmaceutical industry that it has influenced the biomedical literature (259). However, research-based concerns about the risks specific to older drivers have been in evidence for over 50 years (250), without any lucrative blanket-screening assessment having as yet been developed.

Currently, mandatory assessment of older drivers for licensing requirements tends to relate to eyesight testing, certainly in Europe, except where medical professionals or police have raised specific concerns about an individual's fitness to drive. For example, in the Netherlands, Denmark, Cyprus and Ireland, drivers must take an eyesight test at the age of 70, whereas in the UK they make a self-declaration of their medical and visual fitness, but can do this without undertaking any actual assessment (260).

Other types of tests have been linked to crash risk, and may have utility for older driver assessment, but are likely to pick up only those deficits which are brought about by particular types of age-related declines – for example the Rapid-Pace Walk, which measures speed, balance and co-ordination of movement (261). Scores of ten seconds or more have been linked to elevated crash risk (262), but it is entirely possible that drivers with particular types of cognitive impairment would perform quite adequately on this task and thus not be flagged as 'high risk' from the results. Equally, the Block Design Task, a measure of spatial ability deemed to have high ecological validity (263), has been found to be a good indicator of VMC when used as part of a battery of cognitive tests (72), as has the UFOV test (67, 119). VMC is in turn linked to driving performance, but for drivers for whom VMC is not the key issue, these tests are not going to identify them as at-risk. A meta-analysis conducted in 2014 concluded that whilst the evidence indicates that cognitive screening instruments have predictive abilities in relation to older driver behaviour, no single instrument has sufficient validity and reliability in identifying all, or even the majority of unsafe drivers (264). The authors go on to note that the predictive value of screening instruments varies depending on the way in which each assessment approaches the driver measurement process.

Another key issue with driver testing is that any kind of assessment only allows the evaluation of maximal behaviour as opposed to measuring typical behaviour (265). Under test conditions, people either optimise their performance, or experience performance decrements associated with increased stress and cognitive workload; neither of these scenarios are conducive to accurate representation of day-to-day performance. If driver risk-mitigation measures are to be implemented effectively, they must be tailored to the individual and focus on improving specific risk areas – but this can be done only if assessment scores accurately reflect specific elements of driving (158).

A Belgian study published in 2016 concluded that in order to develop effective driving assessment programmes, several functional abilities must be assessed from the start, as opposed to having one initial test acting as a gateway to further testing for those who fail, and release without further follow-up for those who pass (158). This goes against many countries' existing policies, which use a sequential system to overcome the logistical difficulties associated with implementing comprehensive driving assessments that involve cognitive and physiological tests, together with on-road driving assessments. Certainly in the UK, medical professionals – particularly GPs – are held responsible for much of the first-tier screening, as they have contact with the drivers and are delegated the power to refer them for more detailed multidimensional assessments. For this reason it is important that first-tier screening instruments have high validity and reliability in determining safe and unsafe drivers, but the multifactorial nature of driving renders this effectively impossible (64). For example, for drivers with hazard detection difficulties, only a test of attention may reveal these problems; for drivers with longitudinal driving problems, on the other hand, a balance test may be required to identify the issue (158). The same study also concluded that assessments which measure functional abilities only cannot differentiate between safe and unsafe older drivers, as a more contextually grounded approach is required, such as an on-road or simulator-based driving assessment. On-road assessments offer optimal ecological validity (although at increased risk to both the drivers and the assessors), but, given that some older drivers lack familiarity with simulation technology and are less technologically experienced in general than others, and that simulator sickness is a common problem (265), simulator use may negatively impact performance and thus skew assessment results for a subset of the older driver population, compromising the validity of the assessment.

Given the obvious challenges involved in creating a standardised, objective driver assessment that facilitates targeted interventions capable of helping older drivers to self-regulate effectively, it is necessary to turn attention to the resources that are readily available to assist older drivers in calibrating their own self-awareness and implementing appropriate self-regulatory behaviours.

4.2 Self-awareness

It is well established in the literature that self-awareness of driving ability is a key factor in successful self-regulation in older drivers (266, 267), and that drivers lacking that self-awareness present a higher risk to both themselves and others (268). Before drivers consider making a self-regulatory change, they must perceive that a threat exists, otherwise the motivator for change is lacking; but age-related declines are usually so gradual that their impact on driving performance goes undetected (138) until it reaches critical proportions and starts to cause problems. On the other hand, self-regulation without the presence of a threat can impose premature and unnecessary restrictions on driving, potentially leading to negative social and emotional consequences.

Lack of awareness is often exacerbated by cognitive decline, particularly in individuals suffering more serious cognitive impairment (269), but the impact of cognitive decline on self-regulatory behaviour is not clearly established in the literature (61). Self-ratings of ability have failed to predict older drivers' functional performance on measures of cognitive, visual and physical abilities (270), but studies have shown that drivers with established cognitive impairment reported avoiding more situations than those with questionable or no cognitive impairment, which was supported by passenger ratings that indicated clear and frequent self-regulatory behaviours among the impaired group (46). Drivers with questionable cognitive impairment report more difficulties with driving situations than the other groups, something that was also supported by passengers. When asked to rate their own driving performance, cognitively impaired drivers rated their performance as less safe compared with the self-appraisals provided by those with questionable or no cognitive impairment. Cognitively impaired drivers rated themselves as the same as other drivers in their age group, while those without definitive impairment rated themselves as better than other drivers in their age group. The lower self-ratings of the impaired group indicate that they understood that they were experiencing negative performance effects as a result of their age-related declines. (46).

Self-enhancement biases are common to drivers of all ages (271), and their prevalence means that older drivers are not inclined to automatically and spontaneously generate a full and accurate perception of their limitations – the tendency is to overestimate driving performance (5, 268, 271). Self-regulation may be triggered by discomfort under demanding driving conditions, rather than by proactive self-assessment (272), although some studies have indicated that despite drivers reporting discomfort in some higher-demand driving situations, this discomfort was attributed to external factors, such as glare or changes in road layouts, and thus did not act as a catalyst for increased self-awareness (138).

Difficulties specific to older drivers tend to manifest themselves in slow manoeuvring, attentional difficulties (250), health problems (101) and failures to understand their own limitations (273). Their risk is rarely increased by the voluntary risk-taking commonly observed in younger drivers – rather, they fail to respond appropriately to traffic situations despite intending to be safe (101). Their slowness can result in conflicting driving styles between older and younger drivers, particularly at junctions and in other demanding driving situations in which age differences in processing speed are particularly noticeable (274), but these conflicts do not necessarily provoke effective self-assessment processes. However, studies have indicated that driving decision workbooks can promote self-awareness through guided self-assessment (275).

Older drivers using the Driving Decisions Workbook (developed from the late 1990s onwards by the University of Michigan Transportation Research Institute) reported increased awareness of cognitive and operational deficits, which triggered self-regulation processes (275), with 14% becoming aware of changes in their abilities, and 25% reporting intention to change their driving behaviour in order to mitigate the risks associated with age-related declines. This finding is consistent with Anstey et al.'s Multifactorial Model for Enabling Driving Safety, which stipulates that providing older drivers with strategies to accurately assess their own driving performance, and thus put in place self-regulatory behaviours, allows them to ensure that their driving behaviour is consistent with the demands imposed by their functional abilities (266).

Another self-awareness tool that has shown potential safety benefits for older drivers – the OSCAR[3] awareness tool for safe and responsible driving – has been found to increase older drivers' interest in and openness to discussion about driving, as well as increasing their awareness of age-related changes that could negatively impact safe driving, and encouraging engagement with compensatory strategies (276). OSCAR is a document currently available only for research purposes, consisting of 15 questions and 15 related tips on safe driving in older age (277, 278). It is designed to target a range of abilities, including vision, judgement, reaction time, concentration, strength and flexibility, and includes elements relating to driving record and habits, medication and alcohol use. It suggests resources relating to compensatory strategies, courses and assessment. Early validation studies have established its utility in increasing self-awareness among older drivers of age-related changes, and in helping them learn about risk-mitigation strategies and resources (277, 279). The authors of the instrument assert that (277, Abstract):

> "While promoting safe driving and the prevention of crashes and injuries, this intervention could ultimately help older adults maintain or increase their transportation mobility. More studies are needed to further evaluate OSCAR and identify ways to improve its effectiveness."

3 The acronym OSCAR is from the French '**O**util de **s**ensibilisation des **c**onducteurs **â**gés aux capacités **r**equises pour une conduite automobile sécuritaire et responsable' – literally 'Tool for the education of older drivers about the capabilities required for safe and responsible driving'.

Evidence also exists for the effectiveness of an adaptation of OSCAR for relatives of older drivers (OSCARPA – 'PA' referring to caregivers, French 'proches aidants') in improving relatives' interest, openness and knowledge, as well as calibrating their perceptions of changes in older drivers' abilities and use of compensatory strategies (280).

4.3 Family feedback

While many older drivers report that they make their own decisions, many also recognise the role of other people's input in shaping their decision-making processes (281). Key influencers include spouses or partners (282), adult children and other relatives (115), whose feedback can contribute to the implementation of appropriate adjustments to older drivers' behaviours (283), although some studies have found that family and friends have little influence in particular situations – for example, when the driver lives in a rural area (284), where other factors appear to exert greater influence over behavioural outcomes. Studies have revealed that some adult children discourage driving cessation among their parents; this has been attributed partly to concerns about social isolation for the older person, but also to self-interest in that it is avoiding responsibility for provision of alternative transport. Encouraging an elder to modify habits or stop their driving may be motivated by concerns for the safety of older adults adapting to increasingly complex driving environments, perhaps in tandem with declines in their physical abilities (285).

The process of making major life decisions has been studied within the health and social care disciplines, with family members often found to be highly influential, particularly when the older person does not have a spouse or partner (286), although recent research observes that there is no published research evidence that identifies the extent of the influence of members of older drivers' informal social network on their driving decisions (287).

A recent Austrian study (288) observed that there is little evidence in the literature of research examining factors affecting people's propensity to give feedback to older drivers in the aftermath of high-risk incidents. They note that providing feedback which may be perceived as negative is difficult, as critical feedback often provokes negative emotions (289, 290), and it is commonly perceived that criticising people's driving is offensive (288), and leads to acrimonious situations while failing to bring about any positive changes in driving behaviour (291). This well-entrenched social norm – avoiding criticism of others' driving – may be restricting people's willingness to provide feedback, as social norms are powerful determinants of behavioural inhibition (292, 293). However, it is possible that fostering a belief among the broader population that providing feedback to older drivers would be effective might increase the willingness to provide feedback (294).

A previous US survey indicated that feedback rates are low, with only 2% of the older drivers surveyed reporting that they had received any critical feedback (294), although the sample included drivers from the age of 50 up, so the presence of the younger element of the sample may have skewed the findings to some extent. Despite the lack of research evidence on the benefits of critical feedback, there have been studies indicating that front seat passengers often support drivers with the driving task by carrying out supplementary observations at junctions or issuing warnings relating to hazards ahead (195, 216).

Understanding the roles of family members in shaping driving decisions is important when designing interventions to assist with driving support, modification, reduction and cessation (287). Assessment tools such as checklists could be developed to help family members identify relevant driving issues and structure their conversations with the older drivers, and could include guidance for assisting them to make safe decisions about their driving (273). Self-evaluation tools may also be a useful component of the conversation between older drivers and their family members (295).

A recent Australian study (53) identified four key factors affecting older drivers' propensity to accept feedback from an individual:

1. the provider of the feedback must have first-hand experience of their driving;
2. the provider must be a good driver, as perceived by the recipient;
3. there must be sufficient trust that the recipient perceives the feedback as well-intentioned; and
4. the provider must give concrete examples of the behaviours which are subject to criticism.

These findings are consistent with previous research indicating that older drivers prefer specific examples rather than broad discussions about driving regulation (289). Research indicates that for it to be fruitful, feedback should not be delivered on a one-off basis – rather, it should–involve ongoing discussions to assist in understanding recommendations, making adaptive plans, and implementing lifestyle changes (290).

Despite the focus on accepting feedback from people who have personally witnessed their driving and can provide concrete examples of where change may be needed, many older drivers reported the intention to seek confirmation of their requirements for driving adaptation from their doctor, who is unlikely to have direct experience of their driving (287). Feedback tends to be accepted from health professionals, and the majority of older drivers will cease driving if given medical advice to that effect (125, 296). An Australian study reported that 45% of their older driver sample had discussed their driving with their doctors, 43% with their family, and 21% with their friends (297), placing medical professionals (just) at the top of the go-to list for older driver validation. Being so highly regarded as a source of authoritative advice, health professionals require sufficient education about appropriate assessment of fitness to drive, and when and how to report concerns to licensing authorities without compromising the doctor–patient relationship (298, 299). Family members may be able to assist in refining health professionals' assessments by contributing details and experiences of patients' driving (46).

A recent Canadian study (287) identified four domains of family influence on older people, targeting:

1. supporting driving;
2. modification of driving;
3. reduction of driving; and
4. stopping driving.

The most influential statements related to supporting driving and reduction of driving, while those relating to stopping driving had less impact; modification of driving had the least effect. The statements with the highest reported impact in each domain are shown in Table 4.1. A full list of statements by category, with the proportion of drivers rating each statement as highly influential, is shown in Appendix A.

Table 4.1: Highest influence statements

Statement group	Key statements	% of participants rating statement as "high influence"
Support driving	I would feel safe driving with you	81
	Would you please pick up the kids in your car	75
	I prefer that you drive	69
Modify driving	You drive too fast	67
	You are driving too slowly	64
	You need to get your eyes checked, you miss things	64
Reduce driving	Your reflexes are getting slower	81
	Your driving scares me	75
	Your driving has deteriorated	72
Stop driving	How would you feel if you hit a child?	83
	I don't want you to drive your grandchildren	78
	I don't want you to drive any more	75

Source: Adapted from Caragata et al. (288)

Three steps were proposed for implementing optimal family intervention:

1. identify the most appropriate person to discuss driving regulation with the older driver, based on the nature and quality of their relationship, the frequency with which they have observed their driving, and the person's own driving record;
2. establish clear goals for the communication, based on the four statement domains identified in this research, and deliver a consistent message; and
3. identify the habit strength of the older driver and adapt interventions accordingly.

It can be concluded that a lack of feedback and support increases the difficulty experienced by older drivers in effectively self-assessing and making informed decisions about their driving, which causes some older people to cease driving prematurely, while others keep driving for longer than is safe (300). Appropriate feedback, delivered in a manner consistent with older drivers' preferences, may be effective in assisting them to self-regulate their driving and reduce their overall risk on the road.

4.4 Vehicle feedback

Increases in availability of telematics data from vehicles mean that it is now possible to gather continuous data on real on-road driving, rather than just a snapshot of assessed driving, which increases the likelihood of capturing risky driving behaviours (152); this in turn provides the opportunity to give objective feedback to drivers about their performance. This should help older drivers to develop a more accurate understanding of their risk, and allow them to self-regulate on the basis of objective measures rather than subjective experiences (141).

Simulator-based research indicates that feedback improved minimum time to collision, distraction tendency and overall driving performance when the feedback was provided both in real time and retrospectively, and also when given just retrospectively (301), indicating that trip feedback provided after the event can be effective in reducing risk. This is consistent with the findings of on-road research in the USA, in which older drivers received feedback from a system called Trip Diary (141).

The Trip Diary gave feedback on routes selected and on alternative route options with fewer high-risk situations (such as turns across the flow of traffic, U-turns, lane closures, and traffic incidents), and provided a map showing directions for the lower-risk alternative routes. It also reported the frequency of turns across traffic flow, U-turns, speeding, harsh braking, harsh cornering and harsh acceleration events for each trip, which were located on the map to give visual feedback of locations where high-risk behaviours were detected (141). Further details of the metrics gathered and the information displayed to participants can be found in Appendix B.

Despite resistance among older drivers to changing their route choices in response to suggestions from the system (302), feedback from the system reduced their route risk by 2.9% per week, and speeding frequency by 0.9 events per week, equating to a reduction in expected crash rate from 1 in 6,172 trips to 1 in 7,173 trips and a speeding frequency reduction from 46% to 39% (141). The effects on speeding reduction were in line with (although less pronounced than) previous research using telematics devices to report on speed behaviour, which found that they brought about a 75% reduction in speeding violations (303).

These kinds of systems offer a sustainable solution for the provision of long-term feedback with the aim of offering older drivers more effective tools to calibrate their self-assessment and subsequently implement self-regulation It has been suggested that the data gathered by such devices could assist in developing and implementing more effective personalised driver support features, as the system could analyse driving data so as to identify a driver profile that can be used to automatically configure the best support systems to assist the driver (49). The data could even be used to identify the variations within individual drivers' abilities over time and under various road and environmental conditions. When a lack of self-awareness, in combination with age-related cognitive declines, impairs older driver's ability to accurately self-assess their driving performance, and generic self-regulation approaches are not agile enough in their adaptive effects to reduce crash risk (297), the ability to provide personalised feedback on their performance and behaviour may allow them to improve their self-awareness and take appropriate steps to reduce their risk (141).

4.5 Education

Understanding the particular characteristics and behaviours of older drivers is critical for success of education and training intervention programmes (177). Education programmes have been shown to effectively increase awareness and reduce risky driving, but evidence that driver education alone reduces crash rates is limited (76), whilst training interventions have low to moderate effects in improving older drivers' performance (304).

Five presumptions have been proposed for addressing future education for older drivers (273):

1. driving a car will continue to be one element of mobility in the future;
2. older people want to be able to keep driving;
3. safety will be an even more important factor in mobility in the future;
4. 'Green' values will be more important in the future; and
5. innovative technological applications will be more important in the future.

The focus of driver education has recently shifted to encompass ecological (pro-environment) improvement as well as risk-based elements, but these ecological values may be less familiar to older drivers than their younger counterparts who have grown up with ecological problems at the forefront of public consciousness (273). Changes in educational practices also mean that the traditional instructional process whereby information is imparted from instructor to learner has been superseded by new methods in which drivers self-assess, self-motivate and self-regulate, thus taking ownership of their own continuing development process. New technologies can support this process by providing continuous and objective data to inform the self-assessment and self-development process (273).

It has been suggested that older driver education would benefit from a '3A' (Awareness, Appreciation and Assistance) approach (83), with out-of-vehicle training linked directly to on-road training in order to better assess individuals' abilities and tailor the delivery to meet their needs (142). In the case of drivers who have temporarily suspended their driving because of health problems, refresher courses would help them to return to driving with confidence; also, additional content addressing a range of health and other age-related issues should be made available to older drivers (273). It has been suggested that awareness of potential age-related changes relevant to driving could be raised using the media and community-based contact opportunities (such as older people's groups and clinics), and that these could be used as a means of marketing the resources available to older drivers which could help them to develop adaptive strategies, along with conveying messages about their importance in maintaining safe driving (305). The authors also noted that information could be used to help reduce stereotypes, by raising public awareness of both the effectiveness of using adaptive strategies for safe driving and the impact that support from carers and health professionals can offer. Other researchers have called for more efficient methods of conveying information and education about safe driving to older drivers, and to their health professionals, as many older drivers have reported that they have not been educated about the potential impact of their medical conditions on their driving (306).

It is commonly accepted that driver education should be made available to all drivers, but there is far less clarity about the extent to which post-test training and education should be mandatory, and how to make it appealing to the drivers who would benefit from it the most (273). It has been suggested that education for older drivers should not take place in isolation from that directed at younger drivers, and that combining the two, whilst posing a challenge stemming from differences in approaches, may help both groups to understand each other better – and it has pointed out that this reflects the on-road environment in which they are required to interact with one another continuously (273).

4.5.1 Training effectiveness

Historically, training designed to improve cognitive processing speed has been accepted as beneficial for older drivers (36), but in recent years thinking has shifted to the view that a multifaceted approach, one that encompasses physical and visual training, incorporating educational components relating to knowledge and behaviour, may be more effective (307, 308); moreover, new education of older drivers should in the future involve a combination of interventions, which should be assembled with consideration to the situational driving environment and individuals' strengths and limitations (309). It is important to understand how to effectively influence each component, but it is also important to be mindful of potential differences in effects that result when they are combined.

An educational intervention for drivers suffering from age-related visual decline was designed to increase their understanding of the effects of visual declines on driving safety, and to help them employ appropriate strategies to reduce risk, such as driving in daylight and making route adjustments. The intervention was found to increase self-reported strategy use and improve drivers' awareness of the effects of visual declines, but this did not translate into reductions in crash rates two years later (310).

Because visual processing speed declines with age, and this process is associated with increased crash risk, older driver training that aims to compensate for these declines has been developed. A study compared the effects of simulator-based training with visual processing speed training on on-road driving performance, and found that participants who had taken part in the visual processing speed training conducted fewer risky manoeuvres (311), and also that this kind of training was associated with improved reaction times. Another study found that a group of drivers who received visual processing speed training were involved in significantly fewer at-fault crashes over the following six years (312). The evidence on the benefits of visual processing speed training lead researchers to conclude that appropriate training can help older drivers to scan more effectively and allocate their attentional resources much more appropriately (76).

Cognitive training for older drivers is becoming increasingly popular, but the transfer effects to the driving task remain questionable (313, 314), as targeting specific functional abilities may have very limited effects on driving performance, because the amount of variance in driving performance that is explained by individual functional abilities is low (282). Research suggests that context-specific training could be more successful in improving actual driving performance (313–315). Simulator-based training is proposed as a safe, economical and appropriate method of targeting impaired driving functions in a context-relevant manner (158).

There is some debate about the effectiveness of simulator-based interventions, research does indicate that they can improve on-road performance in older drivers (315–318), although simulator sickness has been found to affect high proportions of older drivers – 38% in one study (317). However, US studies using combined classroom and on-road education approaches (AAA and 55 Alive) have, equally, failed to demonstrate clear safety benefits (64; 319), as although the intervention groups showed improved knowledge of safe driving practices and fewer frequent unsafe manoeuvres during a driving test, the studies did not then go on to evaluate the impact on crash rates in the aftermath of the interventions.

Classroom-based training was studied using two different delivery approaches – one involving intensive teaching, and the other being a self-guided course; the intensive programme proved most effective (320). A Canadian review of older driver refresher programmes found that classroom-based and on-road interventions both improve driver performance, but that more focus is required on evaluating their effectiveness (321). Similarly, on-road performance was found to improve after participation in a 12-week-exercise intervention, but no links with crash rates have been identified (319).

It may be beneficial to create specific training for the 'oldest old', as drivers aged over 75 are at the highest risk of crashes (21) and have markedly poorer performance in on-road assessments (74). A recent UK study (142) involved 142 drivers aged 75 and over taking part in a two-hour classroom-based driving course (see Appendix C for topic headings), including 48 aged 80 and over, whose main reasons for participating were to update knowledge, improve driving and confirm their competence. Females drivers were more likely to avoid more demanding traffic situations, while over-80s reported greater self-regulation behaviour. All participants reported finding the intervention useful, and most reported improved driving knowledge, with 80% reporting the intention to make behavioural adaptations accordingly. These findings are consistent with earlier research in Canada (307) which found moderate support for improvements in driving awareness and behaviour as a result of participation in educational interventions, but these improvements did not translate into a reduction in crash rates among older drivers. The UK study (142) also considered self-ratings of driving ability and confidence, and found that pre-intervention ratings were high for both constructs, with only three participants reporting that gaining confidence was a motivating factor for participation, which raises concerns about the appeal of older driver interventions for less-confident drivers who may benefit most from taking part. Interestingly, 11% of drivers reported lower confidence and 20% reduced their self-ratings of driving ability post-intervention, indicating that they developed improved awareness of potential hazards and calibrated their self-evaluation processes, a finding consistent with previous research (174).

The problem of attracting older drivers whose driving is essentially unaffected by age-related declines, rather than those who would really benefit from driver interventions, is a very significant issue affecting older driver risk control on the macro level (273). Focus group data from the UK supports the assertion that competent drivers are more likely to attend older driver interventions than unsafe drivers (142), while researchers in Canada equally encountered self-selection bias in the same way (322). The literature does not offer any firm insights into strategies for overcoming this problem, but it is possible that by using stage-based models to guide people through the self-regulation process more effectively, from a point of being unaware of the potential for age-related declines all the way through to driving cessation, it is hoped that older drivers who can really benefit from the interventions will be motivated to engage with them.

4.5.2 Stage-based models

Recent research has noted that (138: 26nnn):

> "there has been little development of stage-based theories applied to driving self-regulation, and hence a lack of research on theoretically-informed interventions that facilitate older drivers' planning for future self-regulation and even driving cessation."

Interventions should target the needs of each individual and be sympathetic to the stage at which they find themselves in the self-regulation process, with consideration to the environmental, psychological, and social factors influencing driver self-regulation (297).

Australian researchers considered the utility of the stage-based Precaution Adoption Process Model (PAPM; 323) in understanding older drivers' self-regulation (see Table 4.2) (297). The main benefit of the PAPM is that it forms a guidance framework for tailoring interventions to target people at different stages (138). The older drivers were categorised according to the stage of the PAPM which applied to them, with the majority of participants (46.8%) in stage 2 (Unengaged), suggesting that whilst they displayed awareness of age-related effects on driving abilities, they did not believe it applied to them, while 22.1% were in stage 6 (Self-regulating) – although more than two thirds of participants reported reducing their driving exposure over the preceding decade, leading the authors to suggest that the reduction could be attributed to changes in lifestyle preference rather than active self-regulation (297).

Table 4.2: Precaution Adoption Process Model

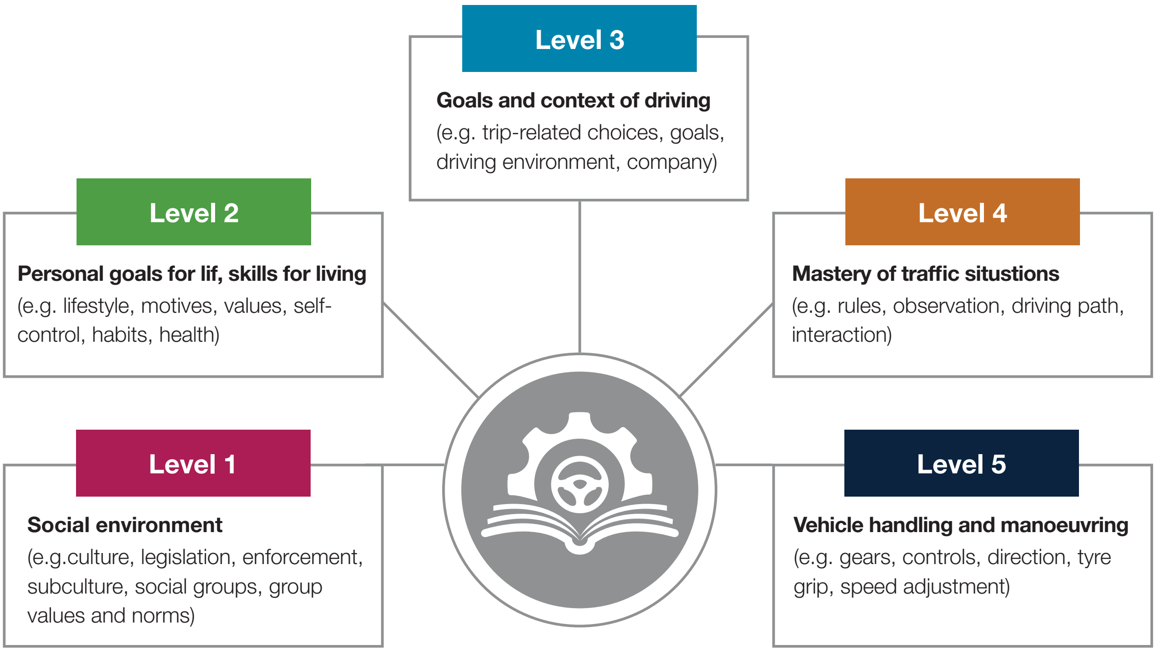
Stage number/description		Characteristic
Stage 1	Unaware	There are no differences between older drivers and younger drivers
Stage 2	Unengaged	Some old drivers need to change their driving, but I believe that I'm a safe driver and have never thought about the need to change my driving
Stage 3	Undecided	I am at the point where I am not sure if I should start thinking about ways to avoid certain driving situations or reduce my driving
Stage 4	Resisting action	Avoiding certain driving situations would be pointless to me
Stage 5	Planning to act	I am planning to avoid certain driving situations and reduce my driving
Stage 6	Self-regulating	I have just recently started to avoid challenging driving situations or drive less

Source: Adapted from Caragata et al. (288)

This model has a lot of commonality with some other well-known models, such as the model of driving comfort (115), and the transtheoretical model of behavioural change (323). However, all of them identify awareness and insight into the existence of a problem as the first step towards self-monitoring and self-regulation, and perception of the risk as personally relevant to motivate them to select and implement behavioural changes (138).

The focus on driver education for all drivers – not just older drivers – has shifted in recent years away from an instructional approach based purely on knowledge or skill, towards a multilayer process whereby the teacher coaches the driver towards a greater understanding of factors influencing their own driving performance (273). The Goals for Driver Education (GDE) model forms a framework for this approach, and in its original four-tier form has been applied to older driver behaviour for over a decade, but it has recently been extended to include the top level, addressing the influence of social environment (see Figure 4.1) (295).

Figure 4.1: The five-level driving hierarchy forming the basis for the Goals for Driver Education



Source: Keskinen (274)

Traditionally, a driving instructor focuses on teaching at the lowest levels of driving hierarchy, imparting knowledge and developing skills, in a downward stream from instructor to learner (324). However, at the higher levels the instructor cannot "teach" the driver using a knowledge-based approach, as progress at these levels relies upon the development of personal insights into the role that personal beliefs, preconceptions, attitudes and behavioural tendencies play in determining their risk on the road. The instructor takes on a coaching role, assisting the learner to become conscious of how these elements apply to them as an individual and how they influence their decision-making and thereby their risk on the road (273).

The fifth level of the GDE, social environment, has been added to GDE to create "GDE5SOC" in response to increasing acknowledgement of the impact of social pressures on driver behaviour, which has been commonly observed in young driver samples (325), for whom the GDE was originally developed, but which has been found to apply equally well to older drivers (326). It addresses culture, legislation, enforcement, subculture, social groups, group values, and norms. Older drivers are just as strongly influenced by social pressures emanating from family, friends, health professionals, the media and a variety of other sources, all of which can influence their perspectives on driving, and ultimately on cessation of driving (273). Research on reasons for driving cessation among older drivers indicated that factors underpinning the decision to stop driving were far more complex than anticipated, with reasons cited which fell into all the different levels of the GDE driving hierarchy, rather than a predominance of health-related reasons (295).

Social skills are those skills required for effective and appropriate interaction with others, but studies of social skills required for driving have revealed (327: 18) that "social skills can be defined as a multistructural system in the areas of human motivation, emotion, and cognition", and as such they form a key element of safe driving. Three key levels are identified (327), each of which have two components: one relates to the driver's own knowledge, observation, understanding and interpretation of social information they receive from their environment (titled 'Internal component' in Table 4.3), while the other relates to the way they choose to interact with the social environment, which will affect their own and others' social perceptions (titled 'External component' in Table 4.3).

Table 4.3: Core components of social skills in traffic

Skill set	Internal component	External component
Prosocial skills	Knowledge of norms	Willingness to follow norms
Anticipating skills	Anticipating the behaviour of other people	Ensuring behaviour can be anticipated by others
Emotional skills	Noticing and understanding others' emotions	Expressing emotions in a constructive way

Source: Adapted from 329

It has been often postulated that driving experience is critical in developing social skills in the traffic environment (328), but the relationship between age and social skills in driving is unclear (329) and no effect of mileage on social skills was detected, contrary to the expectation that experience would be a key influence on drivers' social behaviour on the road (328).

4.6 Supporting effective self-regulation

Self-regulation has been defined (330: 363) as the adjustments made by drivers "in their driving behaviour that adequately match changing cognitive, sensory and motor capacities" and as such it is important that it is not used synonymously with driving cessation, although in many cases driving cessation will be the end point in the process.

Effective self-regulation relies on sufficient self-awareness to accurately monitor driving ability (266), the decision-making capability to select appropriate adaptive strategies, and the self-efficacy to implement them. Patterns indicate that self-regulation increases with age, and that women are significantly more likely than to engage in self-regulation than men (331).

It is well established in the literature that driving cessation is linked to depression (332), social isolation (333), general health decline and mortality (36), and caregiver burden (334). Alternative transport options such as walking, cycling or using public transport are more readily available to the healthier element of the older driver population, so they may be more willing to reduce their driving exposure than those with physical declines, although those healthy older drivers are also likely to experience fewer age-related difficulties, which may reduce their propensity to adopt effective self-regulation, as they may not perceive that there is a risk of age-related declines in their driving performance (252). Equally, those experiencing cognitive declines may by the very nature of those declines lack self-awareness of driving performance problems, so they may also be resistant to advice relating to their driving (115). The use of Advanced Driving Directives (335) as part of 'living wills' or other healthcare directives has been proposed as an effective strategy for encouraging guided self-regulation (287), whereby an older driver specifies someone to assist them in making decisions about driving cessation. It has been suggested that future research should consider diverse populations of older people with representation from different cultures, domestic circumstances and states of health, in order to understand how these factors affect the way in which older drivers' self-regulation is influenced by feedback and interaction with significant others (252).

Older drivers' perceptions of public transport have been found to be negatively oriented, focusing on descriptions such as inaccessible, expensive, inconvenient, unsafe and unreliable (336, 337). Taxis are commonly viewed as expensive and potentially unsafe, while buses and trains are inconvenient and present accessibility problems (338). This negative bias has led researchers to suggest that promoting alternative transport options from a much younger age would prevent these negative perceptions being carried through into older age, thereby overcoming some of the psychological barriers to making the change from private motoring to alternative transport options in later life (339). It has been noted that whilst there are lots of resources for educating drivers about driving, there is little education available relating to safe and effective use of public transport (273).

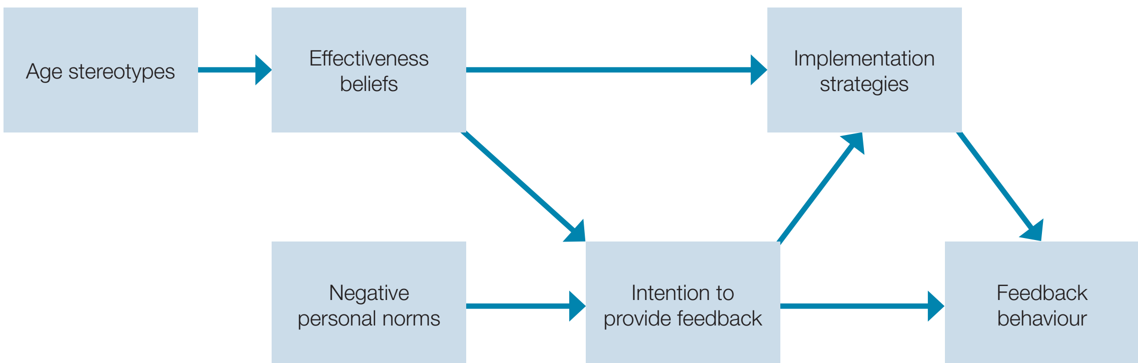
When people have experienced a lifetime of car use as their primary mode of transport, it is difficult for them to give that up even when viable alternatives are in place, and for this reason, even when the intention to use alternative transport is present, the likelihood of alternative options actually being used is reduced by the strength of the habit of driving (340, 341). Driving habits are generally stronger in men, and hence men display greater resistance to driving cessation than women (342). Advice on creating new habits is more effective than criticising the old habit (343), so it has been suggested that introducing new transport habits may be more effective than trying to eradicate old habits – so, for example, over a period of time, a new habit of using a taxi to go shopping may override the old habit of driving (287).

Compliance with social norms may also be effective in encouraging behaviour change in relation to self-regulation and driving cessation, if a transport alternative or other adaptive strategy is perceived as being associated with a particular social group with whom the older person identifies or which they aspire to join. The key social influences for older drivers have been identified as maintaining independence and self-worth, and being connected to life and society (332). Household composition also has a strong influence, as older people who lived alone were less likely to actively self-regulate (273).

Forward planning is critical in effective self-regulation and smooth transition along the path from driver to non-driver. Reactive approaches to encouraging self-regulation or driving cessation are associated with more negative consequences than planned processes (344), but studies have indicated that advanced planning discussions between older drivers and family members are rare (287). Planning gives older drivers a feeling of control over the process, and means that they are likely to have a better quality of life after giving up driving (339). Resources exist to support older people with other major life changes such as retirement, so it has been suggested that traffic researchers should focus on designing interventions that can help older drivers to plan their driving cessation process in a similar way, whilst taking steps to combat stereotypical perceptions that self-regulation is inextricably linked to age-related health issues (138).

Positive age stereotypes are linked to beliefs (on the part of third parties who could offer feedback) that giving feedback on driving behaviour can be beneficial and effective (see Figure 4.2), rather than being ineffective and causing distress to the older drivers (288). Some examples of positive stereotypes about older people include perceptions that they are wise, generous, experienced, loyal, friendly, and reliable (345, 346). Negative stereotypes tend to relate to physical and cognitive declines (347). Common stereotypes dictate that older drivers are viewed as slow, unsafe, shy, nervous, and excessively cautious (348, 349). Recent research has suggested that future studies should focus on the extent to which interventions emphasising positive age stereotypes can increase beliefs that giving feedback to older drivers can be effective, rather than damaging to the relationship, with a view to encouraging people to engage with older drivers to help them with their self-regulation processes in a constructive way (287).

Figure 4.2: Path diagram for the effects of stereotypes on feedback behaviour



Source: Söllner & Florack (289)

5. Conclusions

Concrete relationships between age-related changes and actual crashes are difficult to confirm, because the variation in age-related declines from one individual to another are so enormous, and declines in different cognitive systems can interact in such complex ways, that “it is challenging to unpack relationships between perceptual and cognitive decline and driver comfort and safety outcomes” (76). However, the evidence indicates that perceptual and cognitive abilities decline with age, thus causing the driving task to present more difficulties for drivers as they advance further into old age.

There are two key options for improving older driver risk – either changing drivers’ performance capabilities, or engineering out the risk by changing the traffic environment; and whilst it has been argued that vehicle manufacturers and road engineers have the greatest impact on road safety (308), a review from 2009 revealed that the traffic environment was, in most of the developed world, quite well engineered for older drivers, and further attempts to accommodate their needs may have unintended consequences for the driving behaviour of other groups, which may in fact serve to increase the risk for older drivers, rather than reducing it (1). So, whilst systems approaches to risk management (which acknowledge older drivers’ limitations, and aim to reduce risk by designing vehicles and road environments to accommodate these limitations) are increasingly popular, the emphasis from now on must be placed on helping older drivers to act safely, in terms of their interactions and decision-making within the traffic environment, and also in terms of their interactions and decision-making as regards the self-regulation process (308).

The research evidence indicates that there are gains to be made from helping older drivers to engage in timely, appropriate self-regulation processes, based on well-calibrated self-assessments, and informed by data, from a range of sources, that includes objective measures such as vehicle telemetry and more subjective inputs such as feedback from family members. It is also important that widely held stereotypes about older drivers as a homogeneous group are targeted, in order to reduce preconceptions among the broader population that filter into older drivers' consciousness and compromise their openness to engage with the concept of self-regulation. Simply increasing awareness that 'self-regulation' is not synonymous with 'driving cessation' may be a significant step forward in encouraging more of the older driver population to consider themselves as potential candidates for self-regulation in a timely manner. This would allow them to plan more effectively, which, given the importance of planning for smooth transitioning through the stages of self-regulation, is likely to lead to greater comfort throughout the process, and has been shown to bring about greater satisfaction levels even after driving cessation.

Older drivers must be able to benefit from education schemes that will help them develop a greater understanding of the road conditions and driving situations that present the highest risk to them, and to understand how their specific issues, declines and limitations affect their risk. They require strategies for ongoing self-assessment, and coping strategies that allow them to identify and capitalise on their strengths in order to compensate for their weaknesses. A key component of this is teaching them how to utilise the various information sources available to them that can help them to evaluate themselves accurately and appropriately, and ensuring that they are aware of all sources of driver assistance and risk mitigation, both within the vehicle and in terms of adaptive behavioural strategies, which can help reduce their cognitive workload and increase their confidence – particularly under the driving conditions that they find most challenging. Never before have older drivers had access to so much assistance from vehicle technology, and whilst there were early concerns about a lack of technological familiarity on their part, the literature suggests that appetite among the older driver population for engagement with vehicle technology does exist, and that with appropriate training and guidance, it can offer significant safety benefits and help extend safe driving into older age. On that basis, it appears that the older drivers of today and tomorrow have access to a comprehensive toolkit giving them the opportunity to drive safely for longer than previous generations – the challenge for the road safety industry lies in helping them to use it effectively.

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Appendix A: Influence of statements from family members regarding older driver adaptation

"Support driving" statement	High influence rating (%)
I would feel safe driving with you	81
Would you please pick up the kids in your car?	75
I prefer that you drive	69
There's nothing wrong with your driving	67
You have a good driving record	67
You're a great driver	64
You should not give up driving	64
You can drive there	61
You're a better driver than most people	58
You're as good a driver as anyone	56
I don't think your age has anything to do with your driving ability	47
You're a way better driver than…	39

"Reduce driving" statement	High influence rating (%)
Your reflexes are getting slower	81
Your driving scares me	75
Your driving has deteriorated	72
You can't see as well to drive any more	69
I worry about your driving	67
Your driving is not as good as it used to be	61
You almost had a crash	58
You're going to cause a crash	58
You've already had a crash	56
You can't even shoulder check properly	53
The roads are too busy for you	50
You get lost when you drive	47

"Modify driving" statement	High influence rating (%)
You drive too fast	67
You are driving too slowly	64
You need to get your eyes checked, you miss things	64
You shouldn't drive at night	58
Avoid that busy intersection	58
Take the quiet route	56
You should not be driving on the highway	53
If you drive, I will help with reading the road signs	53
You'll be OK if you drive slowly	44
You shouldn't be taking long trips	44
You should consider taking some driving lessons	33
It's OK if you just drive around your neighbourhood	28

"Stop driving" statement	High influence rating (%)
How would you feel if you hit a child?	83
I don't want you to drive your grandchildren	78
I don't want you to drive any more	75
You're going to kill someone someday if you keep driving	72
You should stop driving now	72
Let me drive	67
You could take a taxi	50
The police will take away your licence	50
I can drive you wherever you want to go	50
You should think about selling your car	39
People your age should not be driving	31
It is too expensive to keep your car	25

Source: Adapted from Caragata et al. (288)

Appendix B: Trip Diary metrics and driver feedback variables from Payyanadan et al. (141)

Table 2: OBD2 device settings and sensitivity metrics

Geotab GO6 OBD2 data	Definition	Measure and sensitivity settings for passenger vehicle
GPS coordinates	Latitude and longitude data for location retrieval.	Event-based
Trip start/stop	A trip starts when the vehicle starts moving. A stop is recorded when the vehicle ignition is turned off, or when the vehicle has a speed of less than 1 km/h for more than 200s.	
Distance	Distance travelled for each trip from origin to destination.	Miles
Time	Time taken to travel for each trip from origin to destination.	Seconds
Speed	Records changes in speed during a trip.	m/s^2, event-based
Acceleration	3-axis accelerometer recordings to determine vehicle acceleration.	Threshold change of 300 milli-G in any direction
Speed violation	Speed is monitored against the posted road speed. If there was no data on the on the posted speed limit for a section of trip, no speed violation was recorded.	5 mph over the posted speed limit
Hard braking	A hard braking incident is recorded when it caused a force of 1/2 G to be exerted on the vehicle.	G-force exertion set at –0.58
Hard cornering	A hard cornering incident is recorded when a hard or aggressive turn causes a force greater than 2/5 G to be exerted on a vehicle.	G-force exertion set at –0.47 and <–0.47

Geotab GO6 OBD2 data	Definition	Measure and sensitivity settings for passenger vehicle
Seatbelt violation	A seatbelt violation is recorded when the driver is not wearing a seatbelt while the vehicle is moving faster than 6.21 mph. This information is communicated through the ECM (electronic control unit) of the vehicle. But not all vehicles transmit information about the seatbelt, hence reporting depended on the type of vehicle driven.	
Engine light	Identifies vehicles driven with the 'Check Engine' light on.	
Possible accident	A possible accident event is recorded when the accelerometer detects a change in speed of more than 15 mph in 1 s in any direction.	

Table 3: Trip diary data displayed to participants during the treatment period

Trip diary data	Definition	Measure/format of information displayed
Geotab GO6 OBD2 data	Table 2	Count
Google and MapQuest data	Google and MapQuest API was used to obtain corresponding route alternatives with lower route risk.	Latitude and longitude
Alternative low-risk route directions	Google and MapQuest APi was used to obtain corresponding lower risk route directions.	
Left turns and U-turns	A left turn algorithm along with manual assessment of routes was used to determine turn count along a driven route. For route alternatives through Goggle and MapQuest, text directions were imported into R to conduct a text search of left and U-turns count. Direction terms for types of turns was determined by manually comparing turns along a route to corresponding map directions.	Count

Trip diary data	Definition	Measure/format of information displayed
Distance	Distance travelled for each participant trip was obtained from Geotab GO6 OBD2 data. Distance for the alternate route was obtained from Google and MapQuest API.	Miles
Time	Travel time for each trip was obtained from the Geotab GO6 OBD2 data. Travel time for alternative route was obtained from Google and MapQuest API.	Seconds
Traffic incidents	511 Wisconsin Department of Transportation (WisDOT) and MapQuest API.	Count
Lane closures	511 Wisconsin Department of Transportation (WisDOT) and MapQuest API.	Count
Route risk	Probability of a crash based on the weighted combination of route characteristics (left turns, U-turns, distance, traffic incidents and lane closures) from NHTSA crash fatality report.	Ratio (relative to the low-risk alternative route)

Appendix C: Dorset County Council older driver course – training framework (140)

Session	Topic	Contents
1	What makes a good driver?	Discussion about relevant experience, having patience, being confident, courteous, having good all-round observation and awareness, driving to the prevailing conditions, passenger empathy (smooth acceleration and braking) awareness of fitness to drive, forward planning.
2	Are you concentrating?	Discussion about how to focus attention for longer on the task of driving and sifting out distractions. What should we be concentrating on? Road signs, markings, speed, road position. Looking for clues in the environment as to potential hazards ahead. Use of static and video images.
3	Distractions	Illustrations of potential distractions inside and outside the vehicle. Use of static and video images.
4	Health and vehicle checks	Medical conditions and medications which may affect driving, maintaining your vehicle, checking tyres and keeping windscreen clean. Use of static images.
5	Highway code	UK guide to driving which forms the basis of the driving test. Short quiz session. Use of static images.
6	Motorway driving	Approaching, lane discipline, avoidance of fatigue, planning well ahead, overtaking, following other vehicles, meanings of signs/ markings. Use of static and video images.
7	Roundabouts	Approaching, lane positioning, leaving and indicating. Use of static and video images.
8	Road markings	Illustrations of the meaning of different road markings. Using local road network as examples. Use of static images.
9	Safety margins.	An explanation of the two-second rule in good driving conditions and lengthening this in adverse weather conditions. Use of static images.

Session	Topic	Contents
10	What is a hazard?	Group discussion sharing ideas on what constitutes a driving hazard. Use of static and video images to highlight potential hazards.
11	Observation	Showing real local scenes, both static and video, for a few seconds and asking what they remember. Also used in the session on “Concentration”.
12	Collisions	How and why they happen, and how to avoid being involved in someone else’s crash. Use of static images to illustrate causes of collisions.

Mobility • Safety • Economy • Environment

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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