Newcastle University e-prints

Date deposited: 14th January 2011

Version of file: Published, final

Peer Review Status: Peer-reviewed

Citation for published item:

Guo AW, Brake JF, Edwards S, Blythe PT, Fairchild RG. The application of in-vehicle systems for elderly drivers. *European Transport Research Review* 2010, **2**(3), 165-174.

Further information on publisher website:

http://www.springer.com

Publisher's copyright statement:

Use Policy:

The application of in-vehicle systems for elderly drivers

Amy Weihong Guo · Jenny F. Brake ·
Simon J. Edwards · Phil T. Blythe ·
Richard G. Fairchild

Abstract

Purpose In response to the rapidly ageing global population, the purpose of this paper is to identify the problems of elderly drivers and their relation to emerging in-vehicle technologies.

Methods The method is three fold. Firstly, it reviews factors involved in the functional decline of elderly drivers. Secondly, it assesses the feedback and support capabilities of in-vehicle systems (IVSs) with the potential to assist elderly people to drive safely for longer and maintain their quality of life. Lastly, it describes a newly funded project, Social inclusion through Digital Economy (SiDE), which will demonstrate an innovative application of driving simulator technology to test and evaluate the impact of emerging invehicle systems on elderly drivers. This project intends to assess whether it makes them less vulnerable road users.

Conclusion The paper concludes that IVSs providing feedback and support to elderly drivers have the potential to help them recognize their weakness and vulnerability as road users and improve their driving performance through the use of advice, alerts, warnings or active interventions.

Keywords Elderly driver · Vulnerable road user · Driver feedback · Driver support · In-vehicle system

A. W. Guo (✉) · J. F. Brake · S. J. Edwards · P. T. Blythe ·
R. G. Fairchild
TORG, School of Civil Engineering & Geosciences,
Newcastle University,
Cassie Building,
Newcastle upon Tyne NE1 7RU, UK
e-mail: weihong.guo@ncl.ac.uk

1 Introduction

In the UK, the ageing segment of the population is growing more rapidly than other age groups. The population of the current state pensionable age is expected to rise by 32% over the next 25 years from 11.8 million in 2008 to 15.6 million in 2033; and the number of people over 85 years is projected to more than double over the next 25 years from 1.3 million in 2008 to 3.3 million by 2033. The proportion of people aged 65 years and over is projected to increase from 16% in 2008 to 23% by 2033 [1]. In Europe, the number of elderly people has tripled over the last 50 years and will more than triple again over the next 50 year period [2]. The same trend is echoed in Canada, USA, Japan and the rest of the developed world. Meanwhile, the number of female elderly drivers has also increased dramatically in the last decade as more of these women started driving in later adulthood or became widowed, divorced or separated and did not have another driver available in the household [3, 4]. This trend will continue in the future and lead to a more even gender distribution among elderly drivers than in the past. These statistics show that the proportion of elderly drivers, particularly female elderly drivers, as a part of the driving population will increase globally and therefore special, targeted care for this segment of drivers should be identified and addressed.

Research suggests that elderly drivers are less accurate in judging speed and distance and have more difficulty with multi-tasking [5, 6]. Robertson and Vanlaar [7] report that in Canada elderly drivers account for 16% of road deaths and 7.8% of injuries—the second largest behind the 15–24 years group. The same study highlights a rate of 15.7 deaths per 100,000 for the 65 years and over group compared to a rate of 24.7 deaths per 100,000 of the population in the 15–24 years group and 9.6 in the 24–

65 years age group [7]. Li et al. [8] show that whilst the number of deaths per driver involved in crashes in the United States is lowest for those aged 16–19 years, it rises by almost fivefold for drivers aged over 80 years. However, in the same study, a measure of fragility can be found by comparing the number of road deaths per number of drivers involved in a crash (a measure of risk) and excessive crash involvement (i.e. drivers involved in crashes per vehicle-miles travelled (VMT)) showed that the rate of drivers involved in crashes per VMT was highest for those aged 16–19 years and falls rapidly until the 70–74 years age group when it rises again. Thus, although the under 24 years age group has a larger crash risk than the over 65 years age group, the over 65 group drives comparatively fewer miles than the under 24 age group, but are more likely to suffer more serious or even fatal injuries, thereby having a higher measure of fragility and vulnerability. Furthermore, elderly drivers also have a problem with maintaining a constant vehicle speed [9].

McGwin et al., [10] showed that for drivers aged 65 years and older, the at-fault crash rate was 2.1 times higher for drivers who had been involved in a crash in the previous 4 years compared to those who had not, herefore an elderly person who has had a recent crash is more likely to have another one. This study also determined that at-fault drivers more often rated their driving as average or worse compared to not at-fault drivers. Habitual hazardous and critical errors highlighted in an Australian on-road driving assessment study of elderly drivers (aged between 60–86 years) showed that failing to check the blind spot, observe intersections and make critical observations (i.e. 'failure to observe critical features of the driving environment that compromised safety including pedestrians on crossings, vehicles entering the flow of traffic, critical traffic signs or road markings') were in the top four reported errors by the assessors [11]. Physical intervention by the instructors resulting from critical driving errors were primarily committed by drivers negotiating intersections, along with failures in observations, gap selection and vehicle positioning [11].

Breker et al. [3] considered that elderly drivers are not often accident prone for the following reasons: they have a lower proportion of alcohol use when driving, use restraints more frequently and do not show signs of losing control over the vehicle in curves and straight sections. However, they are often involved in accidents at an intersection where fast information processing and quick reactions are required. AGILE (Aged people Integration, mobility, safety and quality of Life Enhancement through driving), a project funded by the European Commission Research Programme 'Quality of Life' Key Action 'The Ageing Population', conducted a survey with drivers in three age groups (55–64, 65–74, 75+) in 2001. The results

indicate that the older the age group the person is in, the more often he/she is the following: the main driver in the household, legally responsible for accidents occurring recently, drives fewer miles monthly and is less open to external support such as special training and consultation courses [3]. Gender differences are also found in driving behaviour. Compared to male elderly drivers, female elderly drivers tend to drive fewer mileages; have less driving experience both quantitatively and qualitatively; and are less often involved in or responsible for accidents [3, 4].

However, driving plays an important and essential role in maintaining elderly people's mobility and independent living, enabling them to participate in their usual social activities and carry out practical day-to-day needs [7, 12–14]. From a psychological perspective, driving makes them feel younger, more confident and independent, whilst mobility increases their feeling of control, self-esteem, protection and prestige, enhances their status and helps them participate in work, education or social events and develop cognitive skills. Asking for lifts and the use of public transport could be alternatives to driving. However, UK Economic and Social Research Council (ESRC) research found that older people are exceedingly reluctant to ask family members or friends for lifts, even to hospital or doctor's appointments, unless some kind of reciprocal relationship is involved [15]. Gilhooly [15], AgeUK [16] and Brake [17–19] indicate that barriers to using public transport may exist, such as being physically inaccessible; a lack of covered waiting areas and toilets; the perception of being unsafe and unreliable, expensive and inconvenient; whilst very often services such as hospitals and cheaper out of town shopping centres are poorly served by public transport. In addition, many elderly people are not able to walk the required distance, stand for a long time or have the overall physical endurance to use public transport. Given that both car ownership and driving appear to be related to a higher quality of life, giving up driving can lead to reduced mobility, lack of freedom, loss of independence, unmet social and aesthetic needs, lower quality of life and eventually depression and isolation [12, 15].

This paper reviews factors involved in the functional decline of elderly drivers which is well-documented as the main cause of reduced driving ability. It goes on to assess the feedback and support capabilities of IVSs with the potential to assist elderly people to drive safely for longer and maintain their quality of life. Lastly, it describes a newly funded project, Social inclusion through Digital Economy (SiDE), which will demonstrate an innovative application of driving simulator technology to test and evaluate the impact on elderly drivers of emerging IVSs.

2 Functional decline of elderly drivers

Age-related functional decline in physical health (especially mobility, sight and hearing) and mental health can impact on driving ability and lead to misjudgements and errors whilst driving. Elderly people suffering from a decline in physical health—such as stiffer muscles, limited neck and upper body rotation and loss of upper limb strength—can affect their ability to move and operate the car safely [7, 20, 21]. People suffering from a decline in visual health such as blurred vision and photophobia can experience problems with distance vision and sensitivity to light and glare [20, 22, 23]. Age-related functional decline can also be caused by other medical issues including a stroke, heart disease or medications prescribed to treat a specific ailment or other illness [10, 12, 20, 22, 24]. People suffering from a decline in mental health, such as loss of confidence, memory, concentration and capability to process information, can be more susceptible to distraction, find it difficult to perform multi-tasking and difficult to understand road signs and travel information displayed on the dashboard [12, 20, 22, 25].

In order to compensate for functional decline, elderly drivers tend to drive less: this is possible as they no longer need to commute and travel to work after retirement [12, 26–28]. They deliberately avoid driving at night, in poor road conditions or other risky situations and places such as wet roads, rush hours, heavy traffic, unfamiliar roads and localities, bad weather or damaged roads: these practices all contribute to a reduction in the annual mileage driven [27, 29, 30]. They display a coping mechanism for easing the driving tasks by creating more time. This specific strategy allows them to cope with a reduced capability to process information and allows the task to be completed consciously rather than reactively [5, 31, 32]. This is usually achieved by slowing down before a manoeuvre (such as turning to cross a traffic lane). However, in certain situations, such as entering a high speed motorway, slowing down is not an effective coping mechanism and indeed it may contribute to increasing the risk of an accident. This risky behaviour can be compounded further by physical deficiencies such as reduced neck rotation which can commonly lead to a loss in ability to check the blind spot [11]. They also tend to avoid right turns by taking routes that require left turns or routes where right turns have green-arrow signals [33–35].

3 In-vehicle systems

3.1 Assistance needed to mitigate functional decline

In the literature there are several descriptions of elderly drivers and driving behaviours that can adversely affect driving or can limit the freedom to choose when to drive. Table 1, adapted from Davidse [31], shows a summary of the functional decline affecting elderly drivers and the assistance needed to overcome this functional decline. From this type of information it is possible to begin to scope out the features of assistance systems for elderly drivers.

As discussed earlier, the decline in capability of elderly drivers has contributed to the fact that—compared to middle aged drivers—elderly drivers are more often involved in traffic accidents, killed or seriously injured in accidents which involve other vehicles. Studies of individual developed countries in Europe, Asia and North America [36–39] document that elderly drivers do not represent an excessive risk or a threat to other road users. They are more likely to hurt themselves than to put others at risk. Hence, improving their driving performance has the potential to enhance their safety on the road and benefit the transport network as a whole.

In-vehicle assistive technologies are available to address elderly drivers' functional decline and avoidable behaviours, assist elderly drivers with their driving activities and increase road safety. Rakotonirainy and Steinhardt [40] report that new in-vehicle technology could improve safety and comfort as well as maintain elderly people's mobility for longer. Musselwhite and Haddad [12] point out that older people are quite willing to accept in-vehicle technology that helps their driving, with a slight preference for those that provide feedback rather than reduce workload.

3.2 In-vehicle system capabilities: driver feedback and support

A distinction is made between driver feedback and driver support. Driver feedback offers information (such as location, fuel consumption and the frequency of lane deviation) whereas driver support makes it possible to improve performance based on the information available through feedback (e.g. a better route, how to reduce fuel consumption, how to make fewer lane deviations). Driver support can be in the form of advice, an alert or a warning, or even active intervention. Different IVSs will offer one or more of these capabilities.

In-vehicle navigation systems (IVNS) are common applications using feedback and support. They use a Geographic Information System (GIS), which combines a map and a database, and a satellite navigation system such as Global Positioning System (GPS) [41]. Currently, IVNS typically uses a GPS-enabled device to acquire position data to give feedback by locating the vehicle on the map displayed to the user. Each GPS-enabled device needs to receive signals from at least four satellites to calculate its

Table 1 Functional decline of elderly drivers and assistance needed (Source: adapted from Davidse [31])

Functional decline	Assistance needed
Vision and hearing	
Peripheral vision	Signalling objects that are located in the driver's blind spot
Night time visual acuity	Artificially lighting objects (other road users and road design elements)
Sensitivity to glare	Prevent glare
Contrast sensitivity	Draw attention to approaching traffic
Colour vision	Degree of contrast
Motion perception	Draw attention to approaching traffic
Hearing	Audible cues to visual information display
Cognitive processing and decision making	
Divided attention	Prioritisation of tasks and simplifying sequences of tasks
Selective attention	Assist the driver in directing his/her attention to relevant information
Speed of processing information and making decisions	Provide prior knowledge on the next traffic situation
Performing tasks consciously	Provide prior knowledge on the next traffic situation
Physical changes	
Flexibility of head and neck	Signalling objects that are located in the driver's blind spot
Manual dexterity and strength	Ergonomic design
Interaction with other road users	
Performance under pressure of time	Provide prior knowledge on the next traffic situation
Insight in the behaviour of other road users	Draw attention to approaching traffic and its behaviour

position in three dimensions, therefore an unobstructed view of the sky is required. This means that signal loss and/ or multipath error occurs often in urban canyons or tunnels. A dead reckoning technique (a method of determining position by making an educated guess based on last known position, speed, time and direction), using a gyroscope and an accelerometer is applied to enhance the reliability of IVNS. A system using satellite based, mobile based and wireless technologies was successfully tested in Newcastle during the ASK-IT project (Ambient intelligence system of agents for knowledge-based and integrated services for mobility impaired users, funded by the EU 6th Framework IST programme) to provide both indoor and outdoor location-based services to disabled and elderly people [42]. A future system which integrates GPS with current technologies as well as the forthcoming Galileo system (a European Civil Satellite Navigation system launched by the European Council in 2002) will be able to provide a fully connected and pervasive IVNS.

According to Burns [43] and Goodman et al. [44], IVNS have the potential to maintain elderly drivers' mobility and hence independence and quality of life. For example, they can offer support in the form of advice by providing distance information to identify the location of forthcoming manoeuvres [45], which creates more time for elderly drivers to prepare for the manoeuvres. They help elderly drivers when they travel in an unfamiliar area, where they are often reluctant to travel [45, 46]. It also allows elderly drivers in the early stages of dementia to locate themselves and guide them back home when they are lost, even in a familiar area [47]. However, a safety concern with IVNS using relatively complex visual displays is raised for elderly drivers by Mourant et al. (2001) and May et al. [45]. Also, an age-related decline in learning environment layout (e.g. route selection, scene recognition, distance ranking and map placement) is identified by Kirasic [48] and Moffat et al. [49]. Nevertheless, Guo [46] points out that using snapshots (photographic images) of landmarks for navigation is welcomed by people of all ages. Goodman et al. [44] discovered that a navigation aid based around landmarks is particularly useful for elderly people. May et al. [45] report that the incorporation of landmarks in the turn-by-turn instructions provided by a navigation system has improved the confidence of elderly drivers in particular, because it significantly reduced the time spent glancing on the visual display. Therefore, the use of landmarks as navigation cues can increase the effectiveness and safety of navigation systems.

Connections to the vehicle controller area network bus (CANbus) have allowed information relating to speed,

distance, time of trip, fuel consumption, electrical accessory usage, and heating and ventilation usage to be gained. This information is then used to provide feedback and support. The existence of sensor technology, radio frequency communication-based technology, ad-hoc communication, positioning technology and video image processing technology enables extra information on the driving environment to be collected and interpreted. Examples of such information are distance and/or speed from the vehicle ahead, lateral position of the vehicle on the lane and degree of visibility (e.g. day or night). Integrating them into in-vehicle driver support systems should decrease human errors, alert the driver as early as possible to an impending danger, warn him/her if there is no driver reaction to the first alert and actively assist or ultimately intervene in order to avert the accident or mitigate its consequences [14, 41, 50, 51]. Warnings should be given in visual or audible formats rather than vibrating format as elderly drivers are less sensitive to vibration [52].

Driver support systems have the potential to address either directly or indirectly the specific declines in perceptual, cognitive and physical performance by enabling a reduction in driver workload [41]. Nevertheless, it is important to allow elderly drivers to select when and how much support they wish to receive, thereby increasing user acceptance and subsequent willingness—and capability—to improve their driving performance and road safety [12]. A summary of these driver support systems with the potential assistance to elderly drivers is shown in Table 2.

3.3 In-vehicle system capabilities: methods of delivering feedback and support

Feedback on and support for driving performance can be delivered either in-vehicle (on a display) before, during and at the end of the trip or off-vehicle (e.g. at home or on a mobile digital device) at the convenience of the driver through, for example, emails, websites, mobile phone text messages or paper-based statements. However, Fairchild et al. [53] have suggested that, for feedback to be effective, advice to the driver must be timely and useful, enabling the driver to take action that will improve driving performance in one or more ways, e.g. at the point of the negative behaviour being detected, but without causing a driving hazard in safety critical situations; or after the event whilst still in the car so that there is recent memory of the journey; or off-vehicle, so that more detailed feedback and support can be offered in a non-stressful environment. As many elderly drivers are unaware of their decreased driving performance or are less concerned about relevant issues [7, 54], the use of driver feedback systems will provide opportunities for them to recognise their weaknesses and possibly adopt measures to tackle their diminished driving performance.

One example of off-vehicle feedback is Fiat's eco:Drive system [55]. This measures the driving-style characteristics of the driver which can be downloaded via a universal serial bus (USB) drive. Data are analysed using a Fiat web service when uploaded to the user's home computer. The user is then presented through their web browser with a summary of feedback information such as journey cost and estimated CO_2 emissions, together with support in the form of general tips for better driving.

Foot-LITE is a research project funded by the UK Engineering and Physical Sciences Research Council (EPSRC). It seeks to deliver innovative driver/vehicle interface systems and services to encourage sustained changes to driving styles (to improve safety and eco-driving) and wider travel behaviour (for example switching to non-car modes) [53]. The Foot-LITE system targets drivers from across the socio-economic spectrum and at all levels of experience, making it an appropriate system for use by elderly drivers. The system comprises an in-vehicle device to provide immediate feedback to the driver on a full colour screen that indicates the driving error or risky behaviour that has occurred and provides support showing how it may be corrected and avoided in the future. Further in-vehicle feedback is provided at the end of a trip, indicating journey length, cost (measured by the fuel used) and emissions; it also offers support in the form of 'lessons to be learned'. Finally, statements sent out through the internet at the users' preset timing (e.g. weekly or monthly) provide totals of measured driving factors such as fuel consumption, the number of times a driving infringement was committed, for that time period. It also provides a comparison of how the driver is performing in terms of the changes that have been made in driving style and their impact on the cost of driving and vehicle emissions (which could also increase as well as decrease) over a longer period of time which encompasses multiple trips. Lastly, off-vehicle web based support directs the driver to personalised lessons that will show how to improve their driving style. Driver performance is measured against pre-defined driving standards. The Foot-LITE system has undergone simulator trials fully instrumented vehicle trials and a three vehicle prototype trial; the final field trial will be carried out on a thirty vehicle test fleet.

A more advanced method of delivering feedback and support is the head-up display (HUD). This is a transparent display that presents critical and relevant information to the driver without requiring him/her to look away from the road (Fig. 1). A HUD can be used on forward displays, such as a car windshield, or in rear view/wing mirrors. In March 2010, General Motors announced its new concept: an enhanced vision system that builds upon conventional

Table 2 Driver support systems for elderly drivers (Sources: European Commission [51]; Fairchild et al. [53])

Driver support systems	Assistance to elderly drivers
Adaptive Light Control (ALC)/Adaptive Front Lighting System (AFS)	
Using lighting technology, sensor networks (and satellite navigation systems in the future), ALC/AFS can adjust the direction, width and depth of the headlamps' light automatically in reaction to the surroundings, type of road, steering wheel angle, speed and movement of the vehicle.	Increase visibility at night time and bad weather; offer a better view of the road ahead, including other vehicles and obstacles in the distance.
Lane Departure Warning (LDW)	
LDW is a forward-looking and vision-based system using algorithms to interpret video images to estimate the direction and lateral position and velocity of the vehicle and lane width and road curvature.	Alert the driver to drive within the lane when deviation occurs.
Intersection Assistant	
Intersection assistant monitors the traffic from the right, road signs and the traffic signals at the intersections. Via a wireless communication link, it provides the driver with the status of the traffic lights and a suggested speed to allow him/her to pass the intersections safely.	Alert the driver to stop for the traffic from the right or offer speed suggestions according to the road signs/traffic signals, and then warn the driver if he/she performs inappropriately.
Lane Change Assistance (LCA) or Blind Spot Detection (BSD)	
LCA or BSD continuously monitors the rear blind spots on both sides of the vehicle.	Warn the driver visually/audibly to avoid overtaking in critical situations.
Obstacle and Collision Warning (OCW)	
Using radar sensors or video image processing or a combination of them, OCW monitors the area in front of the vehicle. OCW is proactive in terms of providing full braking force, arming airbags or tightening the seatbelt when needed.	Warn the driver when vehicles, cyclists, pedestrians or other obstacles on the road ahead are detected; prepare the vehicle for an imminent collision proactively to avoid the collision and/or mitigate the severity.
Intelligent Speed Adaptation (ISA)	
Using satellite navigation technology, sensor technology, a road side beacon system and a central control system, ISA constantly monitors vehicles and the local speed limit on a road. ISA can be configured in two ways: advisory ISA and voluntary ISA.	Help the driver maintain a safe speed by alerting the driver (advisory ISA) or decelerating automatically in cooperation with traffic management systems (voluntary ISA) when the speed limit for a given road is exceeded.
Electronic Brake Assist System (EBS)	
EBS can activate the maximum braking power immediately and is triggered when the driver performs fast and hard braking.	Take over the activity from the driver to avoid an accident or decrease vehicle speed at the moment of collision in order to reduce its seriousness.
Adaptive Cruise Control System(ACC)	
Using a long range radar sensor, a signal processor and longitudinal control of the vehicle, ACC constantly monitors the speed of the vehicle and the distance to the vehicle ahead. It will slow down the vehicle when needed and accelerate automatically to the pre-selected speed whilst maintaining the correct distance to the vehicle ahead without requiring any action from the driver.	Take over the activity from the driver to keep a safe distance from the vehicle ahead and avoid collision. The driver can override the system at any time.

HUD technology and displays important information across the entire windshield using cameras and sensors placed around the car (www.wired.com/autopia/2010/03/gm-next-gen-heads-up-display).

As visual impairment is common in elderly people, displaying road signs, speed limit data and traffic signs on the HUD (with optional audible cues) could improve elderly drivers' road safety by enhancing the clarity of road/traffic signs [40]. In addition, elderly drivers, who need an early warning, due to a slower reaction time than younger drivers, will have the chance to decide when they want such information to be made available on the HUD. This will give them enough time (usually longer than for younger drivers) to perform the manoeuvres, before they are able to see the actual sign. This is probably a more effective alternative to 'making road signs bigger to help elderly drivers', as suggested by Box et al. [56]. Moreover, integrating the HUD into IVS has the potential to allow the
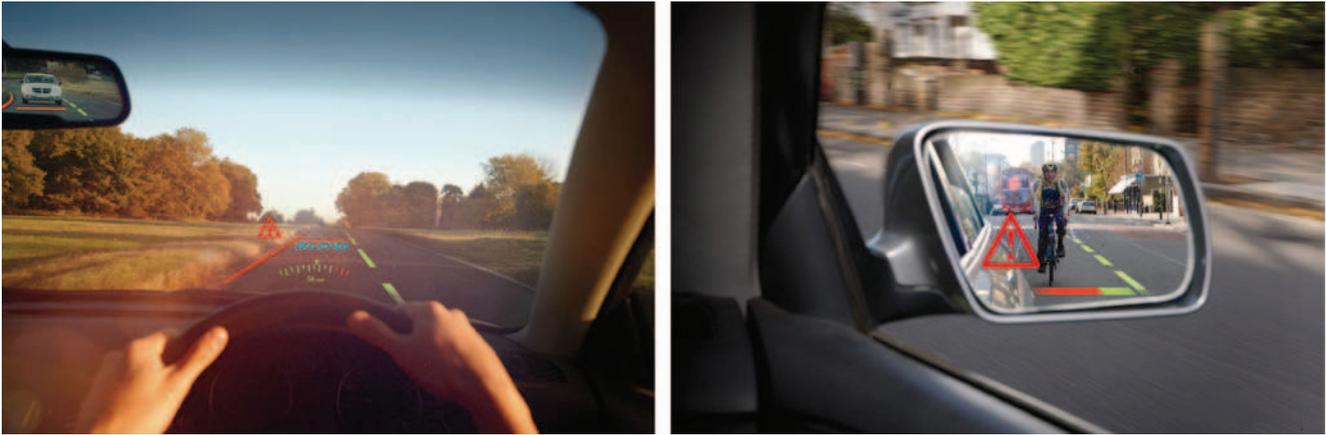
Fig. 1 Head-up displays (Source: www.lightblueoptics.com)

driver to remain focused on the environment outside the vehicle while maintaining the situational awareness of the relationship between the vehicle and the external objects by offering the driver advice along with a bird's eye view of what is around the vehicle and the distances from them. Campbell et al. [57] suggest that a higher sensitivity setting of the interfaces should be available for elderly people because they have poorer visual acuity and are less sensitive to luminance contrasts.

4 Use of a driving simulator to evaluate the impact of in-vehicle systems on elderly drivers

The history of driving simulators can be traced back to the 1920s when simulation was first used to evaluate the skill and competence of public transport operators [58]. Since then, driving simulators have been used to investigate the parameters that govern driver choice and behaviour, driver training and evaluation of vehicle design and technologies. It was pointed out by Yang et al. [58] and Lee et al. [59] that driving simulators give researchers full control of the situational and environmental variables. Also, Breker et al. [60] report that simulation makes it possible to conduct tests in new ways that cannot be realised in real traffic environments. This means that they can conduct observation and evaluation of driver performance and behaviour in relation to the impacts of hypothetical road elements or traffic events. This means that they can avoid potentially hazardous on-road driving conditions and accompanying legal restrictions that may be caused by experiments. It is also a cost-effective alternative to on-road driving tests. The main concern regarding research using driving simulators is the validity of the results. In order to bring high fidelity user experience to the study subjects, it is essential to provide the subjects with the same sensory cues that they experience in real world driving. However, this was not

possible in the past which led to misinterpretation of the signals between the eye and the inner ear. Elderly subjects often suffered motion sickness and had to terminate the experiment early. Furthermore, an older person's ability to act in an unfamiliar technological environment might influence driving performance in the simulator as moderating variable [60]. With the development of motion-cueing algorithms, the current generation of driving simulators (often in a form of the front half or all of a car) are supported by the use of a sophisticated and interactive motion-platform. This platform, which is integrated underneath the driving simulator, is able to provide an immediate understanding of the motion of the vehicle in the simulated world and a valid duplication of the real world driving experience.

Driving simulator technology is being applied in the Social inclusion through Digital Economy (SiDE) project. This has been funded by the Research Councils' UK Digital Economy Programme for 5 years from October 2009. Based at Newcastle University, SiDE will address four fields where digital technologies and the building of a truly inclusive digital economy could deliver major social benefits: Connected Home and Community, Accessibility; Inclusive Transport Services; and Creative Industries.

One of the key studies covered under Inclusive Transport Services is to evaluate whether IVSs underpinned by emerging technologies can assist elderly drivers to drive safely for longer. To understand elderly drivers' behaviour in response to such IVSs, the SiDE project intends to establish driver awareness of their driving capability—and therefore their vulnerability as road users—which can then be compared with their actual functional ability at a later stage. This is different from the AGILE project which focused on establishing an aetiological classification of ageing-related illnesses associated with driving and accidents and gathering knowledge of driver assessment, driver training and traffic safety.

172

Eur. Transp. Res. Rev. (2010) 2:165–174

IVSs will then be tested using a driving simulator (as described above) equipped with a suite of technologies, including in-vehicle sensors (located on the pedals and steering wheel), multiple cameras and projectors, eye tracking and head movement systems and distributed ad-hoc wireless networks. As seen in Section 3, each IVS has a different set of capabilities which will be tested and evaluated individually as well as the whole system. These capabilities will be analysed according to the information that is being delivered (e.g. navigation instructions, lane departure, headway), the reactions made by the subjects (such as braking, accelerating, entering an intersection or high speed traffic) and the degree of personalisation and tolerance of visual load that can be made by the user. After each IVS has been evaluated, there will be a comparative evaluation of all the systems.

Individual driver performance and attitudes to the IVSs will be measured before and after the implementation of each IVS into the driving simulator and its environment. This will permit a sound understanding of the impacts on individual elderly drivers and the scope for adopting these systems. The output of this study will identify the most appropriate combinations of in-vehicle capabilities; the propensity for elderly drivers to adopt these systems; and it will recommend ways of increasing the awareness of elderly drivers about their vulnerability as road users and how it may be overcome using IVSs. The research will also help to identify personalised training needs for individual elderly drivers and to enhance the elderly drivers' understanding of the other drivers' driving behaviour and inform the development of new rules and traffic signs.

5 Conclusion

Elderly drivers are fragile and vulnerable on the road and do not represent an excessive risk or threat to other road users. They are more likely to hurt themselves than to put others at risk. Meanwhile, some of them are more likely to be involved in traffic accidents, be at fault, and are over-represented in traffic fatalities due to age-related functional decline. Also, the ageing population is growing fast worldwide, which is likely to be accompanied by a rise in age related accidents with an inevitable social and monetary cost for society. Neglecting their need for safe driving will lead to a decrease in their quality of life, loss of independence and potentially a high rate of clinical depression.

A review of IVSs suggests that providing feedback and support to elderly drivers has the potential to enhance their safety on the road and benefit the transport network as a whole. Driver feedback offers information on elderly drivers' driving performance and helps them be aware of the misjudgements or driving errors being made. Driver support provides elderly drivers with timely and constructive advice, alerts, warnings or even active interventions which take over the activity from the driver to avoid accidents or reduce the seriousness of the accidents. Driver feedback and support can be delivered either in-vehicle using head-up displays or off-vehicle using a home computer or other personal mobile devices.

A newly funded research project, Social inclusion through Digital Economy (SiDE) will evaluate the impact of IVSs on elderly drivers' driving performance to ascertain whether such systems can assist elderly drivers to drive safely for longer. SiDE will establish elderly drivers' vulnerability as road users based on their awareness of functional decline, and will test a suite of selected IVSs using a driving simulator. It is anticipated that the SiDE project will deliver a sound understanding of the impacts of different systems on elderly drivers, the scope for adopting individual systems or combinations of systems and the individual training needs for safe driving for older drivers. It will also help the elderly drivers' understanding of the other drivers' driving behaviour and inform the development of new rules and traffic signs.

References

1. ONS (2009) Population hub. 2009, Office of National Statistics. Available from: http://www.statistics.gov.uk/hub/population/index.html
2. OASIS (2007) Description of work. Seventh Framework Programme Theme ICT-2007.7.1 ICT&Ageing
3. Breker S, Henriksson P, Eeckhout G, Falkmer T, Siren A, Hakamies-Blomqvist L, Bekiaris E, Panou M, Leue E (2001) Problems of elderly in relation tothe driving task and relevant criticalscenarios. Report Number: AGILE Deliverable 1.1. Available from: <http://www.agile.iao.fraunhofer.de/indexi.html>
4. Oxley J, Charlton J, Scully J, Koppel S (2010) Older female drivers: an emerging transport safety and mobility issue in Australia. Accident Anal Prev 42(2):515–522, Available from: <http://www.sciencedirect.com/science/article/B6V5S-4XJP5X5-1/2/caeabc4b1e805b84b6fb79abc3e0d4c0>
5. Birren J, Fisher L (1995) Ageing and speed of behaviour: possible consequences for psychological functioning. Annu Rev Psychol 46:25, Available from: <http://www.questia.com/googleScholar.qst;jsessionid=LP8L9LjX2XCNpDGWGrd0WhXgPFHHpdn1v02Lxz21FBvZvZ13D4hc!1205579298!-937560419?docId=5001644976>
6. Anderson DS (2004) Strategic planning for mature drivers: foundations and strategies. Center for the Advancement of Public Health MS 1F 5, Department of Health, Fitness and Recreation Resources, Graduate School of Education
7. Robertson R, Vanlaar W (2008) Elderly drivers: future challenges? Accident Anal Prev 40(6):1982–1986

8. Li G, Braver ER, Chen L-H (2003) Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. Accident Anal Prev 35 (2):227–235

9. Musselwhite C, Haddad H (2009) Using grounded theory to elicit the driving needs of older people. In: International conference on Inclusive Design, Royal College of Art, London, UK 5–8, April. Available from: http://include09.kinetixevents. co.uk/4dcgi/prog?sess=28893201042298616082009103543& operation=detail&paper_id=44

10. McGwin G Jr, Sims RV, Pulley L, Roseman JM (2000) Relations among chronic medical conditions, medications, and automobile crashes in the elderly: a population-based case-control study pp 424–431, Available from: http://aje.oxfordjournals.org/cgi/content/abstract/152/5/424

11. Kay L, Bundy A, Clemson L, Jolly N (2008) Validity and reliability of the on-road driving assessment with senior drivers. Accident Anal Prev 40(2):751–759

12. Musselwhite C, Haddad H (2007) Prolonging the safe driving of older people through technology. The Centre for Transport &Society

13. Hakamies-Blomqvist L, Peters B (2000) Recent European research on older drivers. Accident Anal Prev 32(4):601–607

14. van den Broek G, Cavallo F, Vehrmann C (2010) AALIANCE ambient assisted living roadmap. AmbientIntelligence and smart environment. Vol. 6. IOS Press BV, Amsterdam

15. Gilhooly M (2002) Transport and ageing: extending quality of life via public and private transport. Available from: <http://www.esrcsocietytoday.ac.uk/ESRCInfoCentre/Plain_English_Summaries/environment/mobility/index150.aspx>

16. AgeUK (2008) Social inclusion and communities. Available from: http://www.ageconcern.org.uk/AgeConcern/Documents/AA_2008_Social_Inclusion.pdf

17. Brake JF (2008) Identifying appropriate options for delivering urban transportation to older people. In: Urban transport conference. Malta

18. Brake JF (2008) Provision of transport for the disabled and elderly people: taxicard—taxilink preference survey. Contract Report. Nexus

19. Brake JF (2007) Evaluation of older people's community transport shopping pilot. Contract Report. Nexus

20. Dobbs BM (2005) Medical conditions and driving: a review of the literature (1996–2000). National Highway Traffic Safety Administration, Washington

21. Alvarez FJ, Fierro I (2008) Older drivers, medical condition, medical impairment and crash risk. Accident Anal Prev 40 (1):55–60

22. Charlton J, Koppel S, O'Hare M, Andrea D, Smith G, Khodr B, Langford J, Odell M, Fildes B (2004) Influence of chronic illness on crash involvement of motor vehicle drivers. Monash University Accident Research Centre, Victoria, Australia, Available from: <http://www.monash.edu.au/muarc/reports/muarc213.html>

23. Owsley C, McGwin G Jr, Sloane M, Wells J, Stalvey BT, Gauthreaux S (2002) Impact of cataract surgery on motor vehicle crash involvement by older adults. JAMA 288:9, Available from: <http://www.ncbi.nlm.nih.gov/pubmed/12186601>

24. Lyman JM, McGwin G, Sims RV (2001) Factors related to driving difficulty and habits in older drivers. Accident Anal Prev 33 (3):413–421

25. Lundberg C, Hakamies-Blomqvist L (2003) Driving tests with older patients: effect of unfamiliar versus familiar vehicle. Transp Res Part F Traffic Psychol Behav 6(3):163–173, Available from: <http://www.sciencedirect.com/science/article/B6VN8-4979R1N-1/2/f8a140c86a438c15d620ce2d6e22a3a6>

26. Hakamies-Blomqvist L, Wahlström B (1998) Why do older drivers give up driving? Accident Anal Prev 30(3):305–312

27. Raitanen T, Törmäkangas T, Mollenkopf H, Marcellini F (2003) Why do older drivers reduce driving? Findings from three European countries. Transp Res Part F Traffic Psychol Behav 6 (2):81–95

28. Stutts JC, Stewart JR, Martell C (1998) Cognitive test performance and crash risk in an older driver population. Accident Anal Prev 30(3):337–346

29. Ball K, Owsley C, Stalvey B, Roenker DL, Sloane ME, Graves M (1998) Driving avoidance and functional impairment in older drivers. Accident Anal Prev 30(3):313–322

30. O'Neill D (1992) Physicians, elderly drivers, and dementia. Lancet 339(8784):41–43, Available from: <http://www.sciencedirect.com/science/article/B6T1B-49K0B4P-34D/2/923b6e2d21abba789d5577e4e1242a75>

31. Davidse RJ (2006) Older drivers and ADAS—which systems improve road safety? IATSS Res 30(1):6–20, Available from: <http://iatss.or.jp/english/research/30-1/30-1-01.html> [Accessed 21/10/09]

32. de Waard D, Dijksterhuis C, Brookhuis KA (2009) Merging into heavy motorway traffic by young and elderly drivers. Accident Anal Prev 41(3):588–597

33. Hong I, Kurihara T, Iwasaki M (2008) Older drivers' perceptions, responses, and driving behaviours during complex traffic conditions at a signalised intersection. In: IMechE 2008

34. Keskinen E, Ota H, Katila A (1998) Older drivers fail in intersections: Speed discrepancies between older and younger male drivers. Accident Anal Prev 30(3):323–330

35. Salisbury (2009) Positive Ageing Services, in home and community care. City of Salisbury, Salisbury

36. Maycock G (1997) The safety of older car drivers in the European Union. European Road Safety Federation, AA Foundation for Road Safety Research, Basingstoke

37. Evgenikos P, Yannis G, Leitner T, Hoeglinger S, Broughton J, Lawton B (2009) Road safety and the elderly in Europe. In: 4th IRTAD Conference. Seoul, Korea, p 8

38. OECD (2001) Organisation for Economic Cooperation and Development (OECD). Ageing and transport: mobility needs and safety issues

39. Dulisse B (1997) Older drivers and risk to other road users. Accident Anal Prev 29(5):573–582

40. Rakotonirainy A, Steinhardt D (2009) In-vehicle technology functional requirements for older drivers. In: International conference on automotive user interfaces and interactive vehicular applications. ACM, Essen, Germany

41. Bekiaris E (2010) Transport telematics: ADAS & IVICS, from concept to evaluation. Lecture Notes, Newcastle University

42. Edwards S, Fairchild R (2008) The UK pilot site—progress and plans. In: Mobility for all—the use of ambient intelligence in addressing the mobility needs of people with impairments: the case of ASK-IT. Nuremberg, Germany, Available from: http://www.ask-it.org/index.php?page=publications

43. Burns P (1999) Navigation and the mobility of older drivers. J Gerontol B Psychol Sci Soc Sci 54B(1):S49–S55

44. Goodman J, Brewster SA, Gray P (2005) How can we best use landmarks to support older people in navigation? Behav Inf Technol 24(1):18

45. May A, Ross T, Osman Z (2005) The design of next generation in-vehicle navigation systems for the older driver. Interact Comput 17(6):643–659

46. Guo AW (2009) Use of a new methodology to investigate the effectiveness of a pervasive and intelligent future traveller information system in encouraging public transport use. In: School of civil engineering and geosciences. Newcastle University, Newcastle upon Tyne, p 323

47. Brittain K, Robinson L, Lindsay S, Olivier P (2007) Keeping in touch everyday: findings of the scoping stage

174

Eur. Transp. Res. Rev. (2010) 2:165–174

48. Kirasic K (2000) Age differences in adults' spatial abilities, learning environmental layout and wayfinding behaviour. Spat Cogn Comput 2(2):18
49. Moffat SD, Kennedy KM, Rodrigue KM, Raz N (2007) Extra-hippocampal contributions to age differences in human spatial navigation. Cereb Cortex 17(6):1274–1282. Oxford University Press
50. Bekiaris E, Stevens A (2005) Common risk assessment methodology for advanced driver assistance systems. Transp Rev 25(3):11
51. European_Commission (2010) i2010 intelligent car initiative, Europe's information society. European Commission (EC), Available from: http://ec.europa.eu/information_society/activities/intelligentcar/technologies/index_en.htm
52. NHTSA (2007) Traffic safety facts 2007 data: older population. NHTSA, p 6
53. Fairchild R, Brake JF, Thorpe NT, Birrel SA, Young MS, Felstead TJ, Fowkes M (2009) Using on-board driver feedback systems to encourage safe, ecological and efficient driving: the Foot-LITE project. In: The 23rd Convention of the Society for the Study of Artificial Intelligence and Simulation of Behaviour. Edinburgh
54. Lesch MF, Hancock PA (2004) Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? Accident Anal Prev 36(3):471–480
55. Fiat (2009) Fiat eco:Drive [Online]. Published by: fiat. Available from: <http://www.fiat.com/ecoDrive/> [Accessed 01/09/2009]
56. Box E, Gandolfi J, Mitchell K (2010) Maintaining safe mobility for the ageing population: the role of the private car. Available from: <http://www.racfoundation.org/assets/rac_foundation/content/downloadables/maintaining%20safe%20mobility%20-%20rac%20foundation%20-%20140410%20-%20report.pdf> Accessed: [30/04/2010]
57. Campbell JL, Richard CM, Brown JL, McCallum M (2007) Crash warning system interfaces: human factors insights and lessons learned. National Highway Traffic Safety Administration, January
58. Yang CY, Fricker JD, Kuczek T (1998) Designing advanced traveller information systems for a driver's perspective: results of a driving simulation study. Transportation Research Record: Journal of the Transportation Research Board 1621:7
59. Lee HC, Cameron D, Lee AH (2003) Assessing the driving performance of older adult drivers: on-road versus simulated driving. Accident Anal Prev 35(5):797–803
60. Breker S, Rothermel S, Verwey W, Henriksson P (2002) The role of simulation in the assessment of older drivers. Human Factors and Ergonomics Society/Europe Chapter Annual Meeting, Dortmund. Available from: <http://www.agile.iao.fraunhofer.de/publications.html>