Why do older drivers have more ‘failed to look’ crashes? A simulator based study

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A simulator based study

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Contents

Executive summary 4

Aim 4
Method 4
Results 4
Conclusions 4

1 Introduction 6
1.1 Background 6
1.2 Aim 6

2 Literature review 7
  2.1 Visual measures 9
    2.1.1 Visual acuity 9
    2.1.2 Useful Field of View (UFOV®) 9
    2.1.3 Visual search 9
    2.1.4 Visual closure 10
  2.2 Cognitive measures 10
    2.2.1 Hazard Perception 10
    2.2.2 Spatial ability 10
    2.2.3 Task switching and Perceptual speed 11
    2.2.4 Reaction time 11
    2.2.5 Working memory 12
  2.3 Driving simulators 12
  2.4 Summary 12

3 Experimental design 14
  3.1 Participants 14
  3.2 Study tools 14
    3.2.1 Driving simulator: DigiCar 14
    3.2.2 Visual measures 15
    3.2.3 Questionnaires 19
  3.3 Test procedure(s) 20
    3.3.1 Schedule 20
    3.3.2 Simulator familiarisation 21
    3.3.3 Simulator driving tasks 21
  3.4 Study results 23

4 Results 25
Older drivers and ‘failed to look’ crashes

4.1 Participant background information
  4.1.1 Participant demographics
  4.1.2 Participant driving environments
  4.1.3 Accident history
  4.1.4 Driver Behaviour Questionnaire (DBQ)
  4.1.5 Driver Attitude Questionnaire (DAQ)

4.2 Vision and response tests
  4.2.1 Visual acuity
  4.2.2 Useful field of view (UFOV)
  4.2.3 Contrast sensitivity
  4.2.4 Neck flexibility
  4.2.5 Visual closure
  4.2.6 Choice reaction time

4.3 Simulator driving results
  4.3.1 Route 1: Pedestrian hazard
  4.3.2 Routes 2(a) and 2(b): Crossroads
  4.3.3 Route 3: Emerging hazard
  4.3.4 Route 4: Braking vehicle
  4.3.5 Route 5: Motorway driving
  4.3.6 Situational awareness

5 Summary of key results
  5.1 Questionnaires
  5.2 Vision and response tests
  5.3 Simulator driving results

6 Discussion
  6.1 Older drivers and attitudes to driving
  6.2 Older drivers and visuo-cognitive tests
  6.3 Older drivers and simulator driving tests
    6.3.1 Route 1: Pedestrian hazard
    6.3.2 Routes 2(a) and 2(b): Crossroads
    6.3.3 Route 3: Emerging vehicle
    6.3.4 Route 4: Braking vehicle
    6.3.5 Route 5: Motorway driving
    6.3.6 Situational awareness
  6.4 Recommendations
  6.5 Limitations and further work

7 Conclusion
Executive summary

With an increase in life expectancy comes an increase in the proportion of older drivers. As a consequence, the safety of older drivers on our roads is a growing concern, and has become a focus for research and policy initiatives. Various crash studies and surveys have shown that older drivers are particularly over-represented in crashes at intersections, where typically the older driver turns against oncoming traffic with right of way on the main road. A recent report commissioned by the IAM delineated the problem and identified that ‘failure to look’ was the most prevalent contributory factor in accidents involving older drivers relative to young drivers. This study aimed to investigate the correlation between ‘failed to look’ errors and visuo-cognitive deficits in older drivers to build on the work already completed by the IAM.

Aim

This study investigated:

1. How visual capability differs across age groups
2. How visual behaviour when driving differs across age groups.
3. How driving behaviour in vision critical situations differs across age groups

The first phase of the study was to review relevant literature to provide a background to the cognitive and visual measures used. This ensured that the study was using up-to-date and validated measures of cognitive and visual performance. The second phase of the study included simulator and laboratory based tests of visual and cognitive performance, in general and when driving.

Method

The study recruited 32 participants, eight in each of four age categories: Young (17-26 years); Mid (34-55 years); Old-Young (64-74 years) and Old-Old (75+ years). Through their trial session, each participant completed a number of vision and response tests in between driving six different test scenarios in TRL’s driving simulator, DigiCar.

Results

The expected pattern of visual decline was observed across the test battery. However, it was found that older drivers tended to have better, safer attitudes to driving. This was reflected in older drivers tending to adopt slower speeds and achieving the same or better safety margin to emerging hazards. However, it was found that older participants showed poorer positioning at a crossroads and took less time scanning to the left and right before proceeding. It was also found that drivers in the oldest category made far fewer glances to the rear-view mirror when driving on the motorway.

Conclusions

The study demonstrated that older drivers tend to have reduced visual capabilities. In many respects, their experience enables them to compensate for these deficiencies. However, some specific changes in behaviour were observed that seem strongly linked to the tendency for older drivers to be over-represented in ‘failed to look’ accidents.
Support for older drivers to improve performance through training and/or support technologies may help to tackle this problem, although any intervention would require evaluation and validation of effectiveness.
1 Introduction

1.1 Background

With an increase in life expectancy comes an increase in the proportion of older drivers. As a consequence, the safety of older drivers on our roads is a growing concern, and has become a focus for research and policy initiatives. Various crash studies and surveys have shown that older drivers are particularly over-represented in crashes at intersections, where typically the older driver turns against oncoming traffic with right of way on the main road. A recent report commissioned by the IAM delineated the problem and identified that ‘failure to look’ was the most prevalent contributory factor in accidents involving older drivers relative to young drivers. A number of potential mechanisms have been suggested for older drivers’ ‘failure to look’: a failure in situational awareness (SA); inadequate visual scanning (possibly related to SA); and change blindness. Decrement in working memory capability (key to hazard perception, for example) may play an overarching role in the problem.

Age-related changes in cognitive performance independent of the driving task are well documented. Equally well documented are changes in visual functioning: basic visual acuity, peripheral vision, visual acuity in poor light and sensitivity to glare, contrast sensitivity, detection of movement, and colour vision. What is much less well documented is the relationship between these factors and the driving behaviour of older drivers. Do older drivers change their driving behaviour to compensate for physiological changes due to old age? Might this have an impact on the increased likelihood for older drivers to be involved in ‘failed to look’ accidents? This study aimed to investigate the correlation between ‘failed to look’ errors and visuo-cognitive deficits in older drivers to build on the work already completed by the IAM.

1.2 Aim

This study investigated:

1. How visual capability differs across age groups
2. How visual behaviour when driving differs across age groups.
3. How driving behaviour in vision critical situations differs across age groups

The first phase of the study was to review relevant literature to provide a background to the cognitive and visual measures used. The purpose of this was to ensure that the study was using up-to-date and validated measures of cognitive and visual performance.

The second phase of the study included simulator and laboratory based tests of visual and cognitive performance, in general and when driving.
2 Literature review

This section discusses and summarises literature reviewed to inform the choice of supplementary tests and simulator scenarios in the current study. It is by no means an exhaustive discussion of all possible cognitive and perceptual tests available but is instead a review of those that were identified as having most relevance to the study. Search terms were determined by the research team and a literature search was conducted using the TRID (Transport Research International Documentation; http://trid.trb.org/) and the TRL Library databases. The search terms were limited to title, abstract and keyword fields, with the results accepted for any year of publication (to ensure that even older but seminal work was included). Search terms comprised ‘free-text’ terms (our own terms developed as part of the search strategy) and ‘thesaurus’ terms (set terms used by the database abstractors when creating the database records). Research that was identified as having been conducted with older adults was selected to have relevance with the current study and so that results could be compared.

Age-related decline in perceptual and cognitive abilities are well documented (e.g. Salthouse, 2010). However, the application of a general trend in age-related decline to understanding the impact on driving performance is complex; a large proportion of older drivers maintain a good standard of driving performance (Dobbs, Heller & Schopflocher, 1998). Nevertheless, studies of age-related decline in visual function, in particular visual acuity and visual field loss, have been associated with crash risk in older adults (Higgins & Wood, 2005; Owens, Wood & Owens, 2007, Wood, Mcgwin, Elgin, Vaphiades, et al., 2009). However, it is commonly accepted that visual tests alone are inadequate for predicting driving performance (Haymes, Leblanc, Nicolela, Chiasson et al., 2007; Wood et al., 2009) and need to be used in combination with tests of cognitive ability. Anstey, Horswill, Wood & Hatherly (2012) conclude that relying on tests of visual acuity rather than cognitive screening is not the desired approach to assessing older drivers. This review therefore discusses cognitive testing in the main although there is obvious overlap between cognitive and visual components in tests that use visual stimuli to determine performance.

It has been suggested that executive function and processing speed are the key cognitive abilities that contribute to performance decrement when driving (Daigneault, Joly & Frigon, 2002). Andrews and Westerman (2012) use a distinction of cognitive ability proposed by Horn and Cattell (1967) in an attempt to understand the relationship between cognitive decline and driving performance; the distinction is that of ‘fluid’ abilities and ‘crystallised’ abilities. Fluid abilities such as problem-solving, complex reaction time, reasoning and spatial ability are said to be important for responding to novel situations and tasks where completing the task cannot rely on prior knowledge or experience alone. Crystallised abilities reflect acquired knowledge, skills and life experiences. Fluid abilities appear to decline steadily from early adulthood while crystallised abilities are maintained or in fact increase into adulthood (Salthouse, 2010). Several causal mechanisms have been proposed for the age-related decline in fluid abilities such as processing resource capacity, reductions in processing speed, deficiencies in inhibitory processing and increases in neural noise (Salthouse, 1991; Hasher & Zacks, 1988; Welford, 1981). Nevertheless, while types of cognitive processing that are theoretically important to safe and competent driving have been related to ageing, this relationship is not so clear in the real world.
Older drivers’ accident rate is itself complex. When crash frequency is corrected for exposure (e.g. miles driven), older drivers have increased crash risk compared with all drivers other than young, novice drivers (Williams & Carsten, 1989). However, when the negative association between driving distance and crash involvement is taken into account the relationship between age and crash involvement is not so clear (Langford, Methorst & Hakamies-Blomqvist, 2006). However, older drivers do have different types of crashes than younger drivers and are over-represented in multiple-vehicle crashes (Department for Transport, 2009) and crashes at junctions (Clarke, Ward, Bartle & Truman, 2010). The literature therefore supports age-related changes in cognitive performance but not an all-encompassing age-related deficit in driving performance; nevertheless, there appears to be evidence that older drivers’ performance in some critical on-road situations (e.g. at junctions) is compromised by age-related cognitive decline.

It is noteworthy that the lack of clarity regarding how age-related cognitive decline affects driving performance is possibly due to compensatory tactics employed by older drivers. Andrews and Westerman (2012) summarise that evidence supports five possible ways older drivers compensate for age-related cognitive decline. The first is termed ‘strategic compensation’ and simply refers to a conscious or non-conscious choice to avoid driving situations where the older driver feels uncomfortable and at greater risk. For example, avoiding driving at night or in poor weather, or taking a different route to avoid complex junctions. The second compensatory action involves increasing driving-related time parameters. This could be otherwise referred to as increasing the safety margin, usually by driving slower and accepting larger headways.

The third compensatory action is avoidance of unfamiliar situations. As noted above, crystallised abilities are considered to remain and even improve with age but fluid abilities, the ability to adapt to new situations, declines. It is suggested, therefore, that older drivers avoid driving in unfamiliar situations where they may have to rely on fluid ability. The fourth compensatory action involves adapting the processes required for driving to enable best processing from established skills and abilities. For example, proceduralising tasks to avoid dual or multiple task situations. The final compensatory action is termed ‘neural compensation’ and refers to the possibility that older drivers make use of cognitive reserves to maintain driving performance but at the expense of cognitive capacity. Of course, each of these compensatory possibilities is not necessarily mutually exclusive, although there appears to be evidence to support each one individually (see Andrews & Westerman, 2012 for more detail).

The literature on age-related decline suggests that both visual and cognitive decline, particularly decline in ‘fluid abilities’, can be shown to correlate positively with driving performance but that older drivers can compensate for such declines, making it difficult for those attempting to predict crash risk. For this study we are interested in exploring why older drivers are over-represented in ‘failed to look’ (and ‘failed to judge other person’s path or speed’) crashes. It is not required that the results necessarily predict crash risk but instead investigate how tests of visual and cognitive performance relate to driving performance in simulated scenarios where we know that older drivers are more likely to be crash involved (i.e. junctions and complex traffic situations). Illuminating the relationship between these measures will benefit our understanding of why older drivers are over represented in ‘failed to look’ crashes. The remainder of this review therefore summarises tests used by previous studies.
2.1 **Visual measures**

2.1.1 **Visual acuity**

Visual acuity is a straightforward test of participants’ vision. Participants are generally stood a set distance away from a letter chart and asked to read letters of various sizes to determine their visual acuity. It has been known for studies to include this test under both low and high contrast conditions (Anstey et al., 2012). Contrast sensitivity tests are arguably more relevant to the nature of ‘failed to look’ crashes where drivers may have failed to perceive another road user.

2.1.2 **Useful Field of View (UFOV®)**

The UFOV is defined as the area over which a person can extract information in a single glance without moving the head or eyes (Gamache, Hudon, Teasdale & Simoneau, 2010). The UFOV test involves three subtests with increasing difficulty. In subtest one a white, two-dimensional block figure of a car or truck is presented in the centre of the screen. It is followed by a screen of noise and then the participant is asked to indicate whether they saw the car or the truck. In subtest two, an additional car or truck is presented at an angle to the centrally presented vehicle and fixation point. The participant must correctly identify the vehicle presented in the centre of the screen and also the angle at which the second vehicle appeared. Subtest three requires participants to respond in the same way as subtest two although the presentation of the stimuli is distorted by background noise.

It is not necessary to use all three subtests, with subtest two having demonstrated high reliability and validity even when used without subtests one or three in large studies on driver screening (Ball, Roenker, Wadley, Edwards et al., 2006). A statistical association between UFOV performance and on-road and simulator performance and state-recorded crashes has been demonstrated (Gamache et al. 2010; Owsley et al., 1998); although there is debate regarding the predictive ability of the UFOV test and its sensitivity (Bedard, Parkkari, Weaver, Riendeau & Dahlquist, 2010). In a study to determine normative data for older adults, Edwards, Ross, Wadely, Clay et al. (2006) also report sensitivity issues whereby the test was useful for the identification of clear impairment but suffered from individual variability and large standard deviations. They suggest that elucidation of mid-range scores from future research is necessary.

2.1.3 **Visual search**

Dukic and Broberg (2012) investigated older drivers’ visual search patterns at junctions in Sweden. They found that older drivers tended to gaze for longer than younger drivers, suggesting that they required more time for processing visual information, and that they focused more on road markings and static stimuli than dynamic stimuli. Clear differences in neck flexibility were also found with older drivers showing less flexibility when compared with younger drivers. Limited neck flexibility may have been a reason for Rosomer & Fisher’s (2009) finding that older drivers perform fewer side-to-side glances at junctions when compared with younger drivers. Previous studies were inconclusive on this measure with Boa and Boyle (2009) also finding age related differences while Keskinen, Ota and Katila (1998) did not. Boa and Boyle (2009) found that drivers aged 65 to 80 years demonstrated scanning patterns around the front of the vehicle and slightly to the left and the right of the vehicles centre line. They also found that...
compared to younger driver age groups, the older driver group checked fewer times before performing a manoeuvre and were less likely to perform secondary checks. Romoser, Fisher, Mourant, Watchtel, et al. (2005) found that drivers over 70 years old were three times less likely to take a second glance than drivers aged 25 to 55 years. Despite these findings it is not known whether the differences found in these studies are due to physical restrictions or attention deficits.

2.1.4 Visual closure

Visual closure measures the ability to extract visual images from backgrounds and is theoretically important for hazard perception and hazard change detection. Visual closure has been shown to be strongly related to driving performance (Staplin, Lococo, Gish & Decina, 2003; Ball, Roenker, Wadley, Edwards et al., 2006); which may be due to a relationship with hazard perception. Anstey et al. (2012) used a selection of tests adapted from French, Ekstrom and Price (1963) which included Gestalt completion (fifteen incomplete pictures to be identified within three minutes), snowy pictures (fifteen distorted pictures to be identified within three minutes) and concealed words (identifying sixteen incomplete words within three minutes). The snowy pictures and Gestalt completion tests contributed more strongly than the concealed words test to the ‘closure’ factor within Anstey et al.’s factor solution.

2.2 Cognitive measures

2.2.1 Hazard Perception

One of the higher-order skills that improves with continued experience and may partly underlie decreasing crash risk is hazard perception (McKenna & Crick, 1994). Hazard perception skill has been shown to increase with driving experience (e.g. Deery, 1999; Grayson & Sexton, 2002; McKenna & Crick, 1991) and is related to the likelihood of being involved in a road traffic accident (Horswill & McKenna, 2004). The precise mechanisms underlying hazard perception remain unknown although there is evidence for both cognitive and visual search components.

Anstey et al., (2012) used hazard perception as an outcome measure in a simulator study investigating cognitive and visual abilities of driving safety with older adults. Belanger, Gagnon and Yamin (2010) also tested older drivers in challenging simulator situations that can be considered tests of hazard perception. The authors report finding that older drivers were at significantly greater risk of crashing when encountering a hazardous event that required multiple actions. It is further reported that scores of processing speed, cognitive load and attention distinguished between participants who crashed in this scenario and those who did not.

2.2.2 Spatial ability

Spatial ability has been measured using tests of mental rotation and transformation with older drivers (Anstey et al., 2012). The tests involved completing card rotation and paper folding tasks each within a three minute time period. Spatial ability was found to be associated with performance on the Useful Field of View test and Hazard Perception Tests (Anstey et al., 2012). Andrews and Westerman (2012) also used a paper folding test as a measure of special ability and found age related differences where older drivers performed poorly compared to younger drivers.
2.2.3 Task switching and Perceptual speed

Components of attention and executive function are considered important to driving (Miyake, Friedman, Emerson, Witzki et al., 2000) and can be tested by task switching exercises and strategic working memory tests (Anstey et al., 2012). It is however recognised that it is difficult to define executive function and difficult to distinguish it from fluid and working memory abilities (Salthouse, 2005). Task switching and perceptual speed have been measured using the Trail Making Test (TMT) (Anstey et al., 2012; Andrews & Westerman, 2012). The TMT is one of the most widely used instruments in neuropsychological assessment and is used as an indicator of speed of cognitive processing and executive functioning (Sanchez-Cubillo, Parianez, Adrover-Roig, Rodriguez-Sanchez et al., 2009). The test consists of two parts (A and B) with participants having to draw at trail between numbered circles in Part A and between numbers and letters in Part B. While most studies agree that the TMT reliably measures several cognitive mechanisms, there is a lack of consensus about the exact nature of the cognitive processes involved and about their relative contributions to task performance (Sanchez-Cubillo, et al. 2009).

Andrews and Westeman (2012) used the TMT as a measure of fluid ability and found age related differences where older drivers performed poorly compared to younger drivers. Horikawa, Morizono, Koga and Horie (2009) also used the TMT in a study of older drivers' cognitive abilities. In this study participants were split into upper and lower score groups based on responses to this task. Comparison revealed that drivers in the higher scoring group were also better at visual function tests and had better simple reaction time scores.

Visual processing speed is sometimes included in studies as it has been related to several other abilities important for driving (e.g. executive function and working memory). Anstey et al. (2012) found that spatial ability, working memory and perceptual speed were all significantly related to performance on the UFOV test.

2.2.4 Reaction time

Reaction time can be measured as a simple timed response to an event or as Choice Reaction Time (CRT) whereby the participant has to make a decision before responding. The former can be easily tested using a laboratory based test or when driving in the simulator. However, it is well established that physiological decline results in reaction times increasing with age and Choice Reaction Time may therefore be considered a more relevant measure. Choice Reaction Time incorporates cognitive processing and decision making where it is possible that experience and automated processing may compensate for age-related physiological decline. There are several types of CRT tests from PC based tools (e.g. Wood, Anstey, Kerr, Lacherez & Lord, 2008) to simulator based tests such as that used by Burns, Parkes, Burton, Smith and Burch (2002) where the driver had to respond by flashing their headlights when they saw three specific signs among twelve possible signs on the route.

Choice Reaction Time has been used in previous studies measuring age related driving performance and identified differences between younger and older drivers with younger drivers performing better than older drivers (Anstey et al., 2012).
2.2.5 Working memory

Working memory tasks are often based on either digit recall or involve some form of spatial memory task with shapes or the presentation of stimuli in a pattern that is to be recalled. Common tests include adaptations of the Wechsler Adult Intelligence Scale-III (Wechsler, 1997) intelligence test. Working memory is often required for tasks such as task switching and perceptual speed and is therefore not always included as a standalone test.

2.3 Driving simulators

The use of driving simulators to study driver behaviour offers many benefits that can make real world data collection challenging. Firstly, they enable experimenters to devise scenarios that might place a driver at risk of injury if they were conducted using real vehicles. Secondly, they allow driving scenarios to be presented to participants in a highly controlled manner such that participants experience similar conditions between presentations – unlike real driving where traffic, weather and daylight conditions make repeatability more difficult. In addition, they record accurate, high frequency data for numerous variables of interest when studying driver behaviour. Among these are speed, acceleration/deceleration, brake pedal force, vehicle position and distances to other road users. These enable a rich picture of the driving task to be constructed.

Lee, Cameron and Lee (2003) assessed the driving performance of older adult drivers in on-road and simulated driving. Their direct comparison found a highly positive relationship between measurement of both road skills and cognitive/perceptual abilities between the two conditions, leading the authors to suggest that simulators represent a safer, more economical method than on-road testing for assessing the driving performance of older adult drivers.

2.4 Summary

It is important that the tests used in this research to measure visuo-cognitive processing abilities can be theoretically linked with driving ability and performance in situations where ‘failed to look’ or ‘failed to judge other person’s path or speed’ may be most likely. Research has identified and established age related declines in attention, perception, motor processes and memory. It would appear that there are several ways in which drivers affected by age related declines in executive functioning can compensate to reduce their risk of being crash involved. However, driving on the road is unpredictable and it is inevitable that drivers will encounter situations that require the processing of new and unique stimuli rather than relying solely on prior experience. In addition to potentially finding new situations challenging, it would appear that older drivers struggle in situations that require dual or multiple task processing (see Riby, Perfect & Stollery, 2004 for a review).

Identifying specific laboratory tests to capture potential performance decrement in processes related to critical driving situations and ‘failed to look’ crashes is not necessarily clear from the literature. However, there are indications of the tests that are related to important areas of executive functioning. On the basis of the literature reviewed and the focus of this study it is recommended that the following visuo-cognitive and physical measurements are taken:

- Visual acuity
Older drivers and ‘failed to look’ crashes

- Useful Field of View (UFOV®)
- Contrast sensitivity
- Neck flexibility
- Visual closure
- Choice Reaction Time
- Measurement of glance behaviour at junctions
- Hazard perception

These measures should quantify attention, perception, processing and motor function relevant to the types of situations in which it is theorised that older drivers are more likely to be involved in ‘failed to look’ or ‘failed to judge other person’s path or speed’ crashes.
3 Experimental design

3.1 Participants

Thirty-two participants from four age groups were recruited from the TRL participant database to take part in the study. There were equal numbers of male and female participants within each age category:

- 17-25 years
- 35-55 years
- 60-74 years
- 75+ years

At recruitment and on the day of testing, participants were reassured that their performance in the simulator or on any of the other tests had no bearing on the validity of their driving licence. Participants were paid £35 compensation for their time and expenses incurred participating in the study.

3.2 Study tools

3.2.1 Driving simulator: DigiCar

The TRL Driving Simulator (DigiCar) consists of a medium sized family hatchback (Honda Civic) surrounded by four 3 × 4 metre projection screens giving 210º front vision and 60º rear vision, enabling the normal use of the vehicle’s driving and wing mirrors. The road images are generated by PCs running SCANeR Studio software (manufactured by Oktal) and are projected onto the display screens by five Digital Light Processing (DLP) projectors. Images are refreshed at a rate of 60Hz (every 16.7msec) whilst data is sampled at a rate of 20Hz (every 50msec).

![Figure 3.1. TRL driving simulator, DigiCar](image)

Electric motors supply motion with 3 degrees of freedom (heave, pitch and roll) whilst engine noise, external road noise, and the sounds of passing traffic are provided by a stereo sound system.
Two studies have demonstrated the validity of the TRL simulator (Duncan, 1995; Sexton, 1997) and Diels, Robbins and Reed (2012) confirm that the current simulator system is at least as accurate as that used in the Duncan and Sexton studies.

3.2.1.1  **Simulator sickness**

TRL’s driving simulator has a comparatively low rate of participants who are unable to complete driving tasks due to the symptoms of simulator sickness. Simulator sickness is a condition similar to motion sickness experienced by some users of virtual environments. The specific routes used in this trial were relatively benign since the test routes were short (less than five minutes per drive) and contained few symptomatogenic driving conditions such as harsh acceleration/braking or sharp turns.

The incidence of simulator sickness is reduced by careful trial planning (allowing provision of adequate familiarisation and rest periods) and participant management (continuous monitoring of participant condition by trials manager, managing participants’ communication with other participants).

No participants withdrew from the study due to symptoms of simulator sickness.

3.2.1.2  **Visual behaviour**

A video camera in the simulator vehicle recorded the participants face and shoulders when completing the simulator trials. This video feed was combined with data from the simulator showing the driven vehicle’s position within the test route. Post-trial analysis of these videos enabled assessment of participants’ gaze direction throughout the trial. Video coders noted whether participants were looking to the left; to the right; straight ahead or at their mirrors at key locations within three of the six scenarios tested.

3.2.2  **Visual measures**

Participants’ vision was assessed with a selection of tests.

3.2.2.1  **Visual acuity**

Participants’ visual acuity was assessed using a standard Log of Minimum Angle of Resolution (LogMAR) chart (Bailey & Lovie, 1980) – an examples is shown in Figure 3.2. Participants were asked to stand at a marked distance from the chart (1.84m) and to read the letters on the chart using both eyes and whilst wearing any corrective lenses (e.g. glasses or contact lenses) they would normally wear for driving.
Figure 3.2. Example scan of one of the LogMAR visual acuity test charts used in the study
3.2.2.2 Useful field of view

The Useful Field of View (UFOV; Ball & Roenker, 1998) is a computer-based test of visual attention, measuring the visual area in which the participant can process rapidly presented visual information (Owsley et al., 1998). The tests for divided attention (the participant must determine which of two objects was present in the centre box) and selective attention (two objects are presented in the centre box and the participant must determine if the objects are the same or different) were applied with participants completing a practice block of each test before the assessed block. The tests produce a threshold time at which participants were able to make accurate discriminations. Therefore, lower scores represent better performance. Figure 3.3 shows a participant completing the UFOV test.

![Figure 3.3. A participant completing the UFOV test](image)

3.2.2.3 Contrast sensitivity

Assessed using the Freiburg test ([http://www.michaelbach.de/fract/index.html](http://www.michaelbach.de/fract/index.html))

The Freiburg visual acuity and contrast test (FrACT) is a computer-based visual test battery from which the contrast sensitivity test was used. The contrast sensitivity procedure used a forced choice approach (participant must provide a response) in which participants were presented with a single ‘Landolt C’ optotype of fixed size and had to detect its orientation; one of the four orientations shown in Figure 3.4.
Figure 3.4. Landolt C optotypes in the four orientations used in the test

The Landolt C stimulus used complies with the European standard for acuity testing (EN ISO 8596) and is used widely used for such research. Participants used the arrow keys of the computer to indicate whether they thought gap in the C was in the up, down, left, or right position. The process starts with an optotype at high contrast with the light coloured background. If the participant correctly determines its orientation, the foreground-background contrast difference of the optotype is reduced. An incorrect response causes the contrast difference to increase. This process continues for 30 presentations of the optotype, resulting in a threshold contrast for each participant.

3.2.2.4 Neck flexibility when driving

This was assessed with participant sat in a driving position and tested participants’ ability to detect and recognise targets presented behind them. The maximum angle through which participants could detect and recognise targets when viewing over the shoulder to the left and to the right was recorded.

3.2.2.5 Visual closure

Assessed using Ekstrom, French, Harman and Dermen’s (1976) Snowy Pictures test. Participants were shown an example snowy picture of an eye on the left with the same picture on the right with the contour of the picture outlined in red. They were then shown a further seven pictures and asked to detect and identify an object in each picture. Answers were recorded by the experimenter.

3.2.2.6 Choice reaction time

The choice reaction time (CRT) test uses multiple stimuli and response possibilities, thereby placing a greater information-processing load on subjects than simple reaction time. The test uses a series of six outer red light emitting diodes (LEDs) and a central green LED. Close to each LED is an associated light sensitive diode. The device measured CRT by recording the time taken for a participant to shift his/her hand from the light sensitive diode adjacent to the central green LED to the appropriate light sensitive diode adjacent to an outer red LED which became illuminated at random. A new light was only illuminated once the participant had responded to the previous one. However, a maximum CRT duration threshold of 1750 milliseconds applied; CRTs greater than this were recorded as this maximum value. The results gained from the choice reaction time tests can be split into a three categories:
Older drivers and ‘failed to look’ crashes

- Response reaction time: The time between a light being switched on, and a participant moving their finger off the sensor in the centre of the board
- Movement reaction time: The time from the point a participant moves their finger off the central sensor, to the point they make contact with the sensor beneath the light which was activated
- Total reaction time: This is the sum of response reaction time and movement reaction time

Figure 3.5 shows a participant engaged in the CRT test.

Figure 3.5. A participant completing the CRT test

3.2.3 Questionnaires

Participants were asked to complete a questionnaire which included general demographic information and driving history and two standardised questionnaires used to provide further insight into age-related changes in attitudes, behaviour and observed driving performance in the simulator. The Driver Behaviour Questionnaire and Driver Attitude Questionnaire are well used and valuable tools for assessing drivers’ subjective feelings about driving.

3.2.3.1 Driver Behaviour Questionnaire

Participants completed a 30-item version of the driver behaviour questionnaire (DBQ), as developed by Reason, Manstead, Stradling, Baxter, and Campbell (1990). Participants indicated how often they find themselves in particular aberrant driving situations on a
scale of 0 (never) to 5 (nearly all the time). It produces scores on four subscales: Errors; Lapses; Violations and Positive Behaviours.

3.2.3.2 Driver Attitude Questionnaire

Participants completed a 40-item version of the Driver Attitude Questionnaire (DAQ), as developed by Parker, Stradling and Manstead (1996). This has four subscales, each of which has ten items relating to drink driving; following closely to other vehicles; risky overtaking and speeding. Participants respond with their level of agreement (on a five-point Likert scale) with statements relating to each subscale. Half of the statements for each subscale portray what would typically be considered as safer attitudes towards road safety (e.g. 'I would be happier if speed limits were more strictly enforced') and the other half portray less safe attitudes (e.g. 'Close following is not really a serious road safety problem'). Agreement scores towards the less safe items are reversed to produce an overall safety of drivers’ attitudes towards each factor.

3.3 Test procedure(s)

Participants were selected from the TRL database of around 2,000 volunteers according the recruitment constraints listed in 3.1. To reduce the likelihood of participant dropout, preference was given to members of the public who had previously driven the simulator vehicle.

3.3.1 Schedule

Participants completed the trial as per the schedule in Table 3.1. Participants were recruited to attend in pairs and alternated between simulator drives and vision tests. Test drives 1-6 represent the six simulator routes and were completed in a counterbalanced order between participants.
Table 3.1. Trial schedule

<table>
<thead>
<tr>
<th>Start time</th>
<th>End time</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>00:10</td>
<td>Arrive, welcome</td>
</tr>
<tr>
<td>00:10</td>
<td>00:25</td>
<td>Familiarisation drive</td>
</tr>
<tr>
<td>00:25</td>
<td>00:35</td>
<td>Visual acuity test</td>
</tr>
<tr>
<td>00:35</td>
<td>00:45</td>
<td>Test drive 1</td>
</tr>
<tr>
<td>00:45</td>
<td>00:55</td>
<td>UFOV</td>
</tr>
<tr>
<td>00:55</td>
<td>01:05</td>
<td>Test drive 2</td>
</tr>
<tr>
<td>01:05</td>
<td>01:15</td>
<td>Contrast sensitivity test</td>
</tr>
<tr>
<td>01:15</td>
<td>01:25</td>
<td>Test drive 3</td>
</tr>
<tr>
<td>01:35</td>
<td>01:45</td>
<td>Neck flexibility</td>
</tr>
<tr>
<td>01:45</td>
<td>01:55</td>
<td>Test drive 4</td>
</tr>
<tr>
<td>01:55</td>
<td>02:05</td>
<td>CRT</td>
</tr>
<tr>
<td>02:05</td>
<td>02:15</td>
<td>Test drive 5</td>
</tr>
<tr>
<td>02:15</td>
<td>02:25</td>
<td>Snowy Pictures</td>
</tr>
<tr>
<td>02:25</td>
<td>02:35</td>
<td>Test drive 6</td>
</tr>
<tr>
<td>02:35</td>
<td>02:45</td>
<td>Questionnaires</td>
</tr>
<tr>
<td>02:45</td>
<td>02:50</td>
<td>Depart</td>
</tr>
</tbody>
</table>

3.3.2 Simulator familiarisation

Participants were given standard instructions before driving the simulator. They were asked to ‘drive as you normally do’ and told that their ‘driving is not being judged’ and they ‘should not treat the simulator like a computer game’.

Even though all participants were previous users of the driving simulator, it is still beneficial to have a short familiarisation drive on each visit to become re-acquainted to the simulator vehicle and the feeling of driving in a virtual environment.

This drive lasts between five and ten minutes and was through a benign rural driving environment. Since aspects of this trial involved approaching and pulling away from junctions, participants practiced braking to a stop and accelerating from stationary within the familiarisation drive.

3.3.3 Simulator driving tasks

Six different scenarios were completed by participants.

Route 1: Pedestrian hazard

- Participants drove on a short stretch of two lane road for approximately 30-60 seconds
- Participants encounter a truck parked on the driven lane with its hazard warning lights flashing. Where the truck is parked, adjacent to the opposing traffic lane, was a bus stop with pedestrians apparently waiting for the bus
- As the participant manoeuvres their vehicle around the parked truck, a pedestrian was triggered to cross the road from behind the truck towards the bus stop. This required braking but not an emergency response.
• Shortly after the pedestrian, the participant was asked the colour of the pedestrian’s top.
• Response measures:
  o Speed of vehicle negotiating the parked truck (measure of caution)
  o Speed of brake pedal application (measure of speed of response)
  o Distance to pedestrian when stopped (measure of success of response)
  o Accuracy of recall of pedestrian detail (measure of observation)

Route 2(a): Crossroads (no vehicles)
• Participants drove on a short stretch of road for 30-60 seconds before reaching a crossroads demarcated with a stop sign.
• Participants were required to continue straight ahead at the crossroads.
• No other traffic was present at the crossroads to impede progress
• Response measures:
  o Speed of vehicle on approach to the crossroads (measure of speed choice)
  o Deceleration rate on approach to crossroads (measure of harsh driving behaviour)
  o Visual scanning behaviour in deciding when to proceed across the crossroads (measure of visual behaviour)
  o Number of head turns performed to check for traffic during the manoeuvre (measure of physical motion)
  o Time taken to proceed across the crossroads after stopping at the junction (measure of driving behaviour)

Route 2(b): Crossroads (vehicles)
• As above except a stream of traffic passed the crossroads from the right of the driven vehicle.
• After setting off across the crossroads, participants were asked to recall the colour of the last vehicle to pass before they decided to proceed.
• Response measures:
  o Speed of vehicle on approach to the crossroads (measure of speed choice)
  o Deceleration rate on approach to crossroads (measure of harsh driving behaviour)
  o Visual scanning behaviour in deciding when to proceed across the crossroads (measure of visual behaviour)
  o Number of head turns performed to check for traffic during the manoeuvre (measure of physical motion)
  o Time taken to proceed across the crossroads after stopping at the junction (measure of driving behaviour)
  o Accuracy of recall of vehicle detail (measure of observation)

Route 3: Emerging hazard
• Participants drove along a country lane for 30-60 seconds.
• After this time, the road became hedge-lined with several obscured entrances to the left.
• After passing several such entrances, a vehicle emerged suddenly from such an entrance into the driven lane.
• Response measures:
  o Speed when driving along the country lane (measure of speed choice)
  o Speed of brake pedal application (measure of speed of response)
  o Distance to vehicle when stopped (measure of success of response)

**Route 4: Braking vehicle**
• Participants started behind a lead vehicle which set off when the participant initiated the drive.
• After driving for around 60 seconds, the lead vehicle braked suddenly and without warning (not emergency braking)
• Response measures:
  o Time headway to lead vehicle when following (measure of caution)
  o Speed of brake pedal application (measure of speed of response)
  o Distance to lead vehicle when stopped (measure of success of response)

**Route 5: Motorway driving**
• Participants drove on a standard motorway in traffic for 5-10 minutes.
• Response measures:
  o Speed choice (measure of speed choice)
  o Time headway to other vehicles (measure of caution)
  o Visual scanning behaviour in normal motorway driving (measure of visual behaviour)

### 3.4 Study results

There were three sources of data:
• Driving performance as recorded during drives.
• Visual behaviour as observed from the recordings of participants in the simulator.
• Results from the non-simulator measures.

Simulator data were recorded at 20Hz. Items recorded in the data were as follows:
Table 3.2. Simulator data recorded at 20Hz

<table>
<thead>
<tr>
<th>Data</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Time elapsed since the start of the trial</td>
</tr>
<tr>
<td>X position of interactive vehicle</td>
<td>The X position of the interactive vehicle within the map of the simulated environment.</td>
</tr>
<tr>
<td>Y position of interactive vehicle</td>
<td>The Y position of the interactive vehicle within the map of the simulated environment.</td>
</tr>
<tr>
<td>Z position of interactive vehicle</td>
<td>The Z position of the interactive vehicle within the map of the simulated environment.</td>
</tr>
<tr>
<td>Speed</td>
<td>Current speed of the interactive vehicle</td>
</tr>
<tr>
<td>Distance through trial</td>
<td>Distance travelled by participant relative to the start of the virtual road</td>
</tr>
<tr>
<td>Lateral distance from centre of road</td>
<td>The distance of the centre of the interactive vehicle from the centre of the road</td>
</tr>
<tr>
<td>Headway</td>
<td>The distance headway between the interactive vehicle and the back of any vehicle ahead.</td>
</tr>
<tr>
<td>Time Headway</td>
<td>The time headway between the interactive vehicle and the back of any vehicle ahead.</td>
</tr>
<tr>
<td>Accelerator pedal</td>
<td>Current proportion of accelerator pedal depression.</td>
</tr>
<tr>
<td>Brake pedal</td>
<td>Force of brake pedal depression (Newtons).</td>
</tr>
<tr>
<td>Clutch pedal</td>
<td>Current proportion of clutch pedal depression.</td>
</tr>
<tr>
<td>Steering wheel</td>
<td>Current angle of steering wheel rotation</td>
</tr>
</tbody>
</table>

Simulator data was post-processed using Microsoft Excel 2010 and analysed using the statistical software package IBM SPSS 19.0. A statistical result producing a p value below 0.05 will be taken as significant and error bars where shown on charts represent the 95% confidence interval on the mean. Simulator data was integrated with questionnaire data and the results of the visual tests to enable cross-examination.
4 Results

4.1 Participant background information

4.1.1 Participant demographics

Table 4.1 shows information about the trial participants; recruitment successfully met the criteria outlined in 3.1.

<table>
<thead>
<tr>
<th>Age group</th>
<th>N (M/F)</th>
<th>Age (years)</th>
<th>Years since licence acquisition (years)</th>
<th>Estimated annual mileage (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>8 (4/4)</td>
<td>21.3 (17; 26; 2.66)</td>
<td>3.69 (0.5; 7.0; 2.09)</td>
<td>5,200 (900; 10,000; 4,316)</td>
</tr>
<tr>
<td>Mid</td>
<td>8 (4/4)</td>
<td>42.3 (34; 49; 4.71)</td>
<td>22.9 (15.0; 29.0; 5.41)</td>
<td>11,000 (1,500; 20,000; 6,053)</td>
</tr>
<tr>
<td>Old-Young</td>
<td>8 (4/4)</td>
<td>68.9 (64; 73; 3.00)</td>
<td>43.3 (22.0; 53.0; 11.0)</td>
<td>5,813 (3,000; 10,000; 2,902)</td>
</tr>
<tr>
<td>Old-Old</td>
<td>8 (4/4)</td>
<td>78.5 (75; 81; 2.14)</td>
<td>50.1 (36.0; 61.0; 7.97)</td>
<td>5,938 (500; 13,000; 4,161)</td>
</tr>
<tr>
<td>Total</td>
<td>32 (16/16)</td>
<td>52.7 (17; 81; 23.1)</td>
<td>30.0 (0.5; 61.0; 19.8)</td>
<td>7,045 (500; 20,000; 4,897)</td>
</tr>
</tbody>
</table>

Due to recruiting time constraints, one participant was one year older than the intended Young age category and one participant was one year younger than the intended Mid age group. All other participants were within the planned age categories.

Drivers in the Young age group reported covering the lowest annual mileage; although drivers in both the Old categories had similar mean annual mileages of between 5,000 and 6,000. The Mid age group drivers stand out as typically covering more miles per year than the other age groups.

4.1.2 Participant driving environments

Participants reported their estimate of the percentage of their driving they completed in motorway, urban and rural environments.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Motorway (mean %)</th>
<th>Urban (mean %)</th>
<th>Rural (mean %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>40.8</td>
<td>34.4</td>
<td>25.5</td>
</tr>
<tr>
<td>Mid</td>
<td>29.9</td>
<td>50.4</td>
<td>17.5</td>
</tr>
<tr>
<td>Old-Young</td>
<td>26.3</td>
<td>44.4</td>
<td>29.4</td>
</tr>
<tr>
<td>Old-Old</td>
<td>20.0</td>
<td>58.8</td>
<td>21.3</td>
</tr>
<tr>
<td>Total</td>
<td>29.2</td>
<td>47.0</td>
<td>23.4</td>
</tr>
</tbody>
</table>

It can be seen that there is a greater tendency for drivers in the Young age group to drive on motorways, despite covering a lower annual mileage (see Table 4.1). Drivers in
Older drivers and ‘failed to look’ crashes

The Mid age category report driving fewer miles in Rural environments than the other categories. Drivers in the two eldest categories show broadly similar driving patterns, with the Old-Old drivers conducting the lowest proportion of their driving on motorways.

The annual mileage of participants observed across age groups reflect the relative differences in annual mileage between age groups shown in the Department for Transport national travel survey statistics (Department for Transport, 2011). The mean annual mileage figures for each age group are slightly higher than the national average but this can be accounted for by participants being recruited from a semi-rural location in South-East England where annual car driven mileage is typically higher.

4.1.3 Accident history

Of the 32 participants, four reported being involved in a road accident in the last five years in which they were a driver. Two were from the Young category and one each from the Mid and Old-Old age groups.

4.1.4 Driver Behaviour Questionnaire (DBQ)

The DBQ produces scores on four subscales: Violations, Errors, Lapses and Positive Behaviours. Results showed that there were no significant differences between any age groups on any of the subscales of the DBQ. However, there was a significant correlation between Violation scores and participant age (N = 32; r = -0.370; p = 0.037). This suggests that older drivers are less likely to engage in driving violations. Figure 4.1 shows the mean DBQ Violation scores for each age group.

![Figure 4.1. Error bar chart showing mean DBQ Violation scores across age groups](image)

Figure 4.1 shows that participants in the Young category have the highest mean and the greatest variability in their DBQ Violation scores.

**Key result:** Driver behaviour questionnaire scores indicate that older drivers are less likely to engage in driving violations whilst younger drivers show more variable DBQ Violation scores.
### 4.1.5 Driver Attitude Questionnaire (DAQ)

The DAQ produces attitude scores on subscales in relation to four aberrant driving behaviours: Drink driving; Close following; Dangerous overtaking; Speeding. Results showed that there were no significant main effects of age groups on any of the subscales of the DAQ. However, the Close following and Dangerous overtaking scores both showed a significant correlation with participant age (Close following: \( N = 30; r = 0.385; p = 0.036 \); Dangerous overtaking: \( N = 30; r = 0.390; p = 0.033 \)). This suggests that older drivers have safer attitudes toward these behaviours. Figure 4.2 shows the mean scores for each age group on these subscales of the DAQ.

Figure 4.2 (a) and (b) shows that older drivers tend to have higher scores on the DAQ for the Close following and Dangerous overtaking subscales. Higher scores reflect better, safer attitudes towards these driving situations. In terms of Close following, Old-Old drivers have the safest and most consistent scores whilst for Dangerous overtaking, Old-Young drivers show the best attitudes. Although the non-significant ANOVA tests showed no main effect of Age group, post-hoc comparisons showed that Old-Young drivers had significantly higher scores than the Young and Mid age groups on the Dangerous overtaking subscale.

**Key result:** Driver attitude questionnaire scores indicate that older drivers have safer and more consistent attitudes towards close following and dangerous overtaking.
4.2 Vision and response tests

4.2.1 Visual acuity

Participants’ visual acuity was calculated as LogMAR score based on the number of letters they were able to read from the standard LogMAR chart. The LogMAR score relates to the minimum angle of resolution, therefore lower scores are associated with an ability to resolve smaller letters, indicating better acuity. Mean scores across the age groups are shown in Figure 4.3.

Figure 4.3 shows the expected result – acuity worsens with age. An ANOVA test confirms there are significant differences between age groups ($F(3, 28) = 4.631; p = 0.009$). Post-hoc comparisons show that this significant difference is caused by the Young group having significantly better visual acuity than all other groups. All participants recorded acuity that was better than that required to pass the vision test included in the UK practical driving test – reading a new-style number plate from 20 metres. To confirm this result, a highly significant positive correlation was found between LogMAR score and age ($N = 32; r = 0.562; p = 0.001$).

**Key result**: Visual acuity tends to decrease with age.
4.2.2 Useful field of view (UFOV)

Figure 4.4 shows participants’ threshold times on the (a) divided attention and (b) selective attention tasks, split by age group. One participant in the Young category failed to complete the UFOV tests.

(c) Divided attention
(d) Selective attention

Figure 4.4. Error bar charts showing mean threshold scores on the UFOV divided attention and selective attention subtests across age groups.

Figure 4.4 shows that performance shows a tendency to decline with age and that performance in the older groups is more variable than that in the younger groups. ANOVA tests indicate that there is a significant main effect of age group for selective attention (F(3, 27) = 13.4; p < 0.001). Post-hoc comparisons demonstrate that adjacent age groups (e.g. Young vs. Mid, Mid vs. Old-Young etc) do not differ significantly from each other but differences between non-adjacent groups (e.g. Young vs. Old-Young; Mid vs. Old-Old etc.) are significant. The correlations between age and both UFOV thresholds is significant (Divided attention: N = 31; r = 0.439; p = 0.014; Selective attention: N = 31; r = 0.771; p < 0.001).

**Key result:** Useful field of view declines with age although the magnitude of the decline varies suggesting large individual differences.
4.2.3 Contrast sensitivity

The contrast sensitivity test produced a Weber score for each participant indicating a threshold contrast difference between the luminance of the target and that of its background. Lower scores therefore represent better contrast sensitivity. Figure 4.5 shows the Weber scores observed across age groups.

![Figure 4.5. Error bar chart showing Weber contrast sensitivity across age groups](image)

The data shown in Figure 4.5 does not include two outliers (one from the Old-Young and one from the Old-Old age groups) – each of which had Weber scores that suggested far lower contrast sensitivity than that typical of their respective age group. The computer-based test failed to work for four participants (two from the Young and two from the Old – Young age groups). However, an ANOVA test on this reduced dataset still produced a significant result \( F(3, 22) = 5.715; p = 0.005 \), with post-hoc comparisons showing that this was driven by the Old-Old group having significantly worse contrast sensitivity than all other groups. Contrast sensitivity shows a significant positive correlation with age \( (N = 26; r = 0.539; p = 0.004) \).

**Key result:** Contrast sensitivity thresholds decline with age; although again the variability increases with age suggesting large individual differences.
4.2.4 Neck flexibility

Participants were asked sit in a driving position and turn in each direction to detect target visual stimuli presented behind them to test their horizontal range of vision.

Figure 4.6. Error bar chart showing range of horizontal vision for participants looking right and left to detect visual targets presented behind them across age groups

Figure 4.6 shows apart from the Old-Old group, participants were able to detect targets presented more than 180° round from the ahead position to the left and to the right and that horizontal range of vision decreased in the older age groups. ANOVA tests show a significant difference between age groups for range of vision to the left (F(3, 28) = 3.040; p = 0.045) and near-significant difference for range of vision to the right (F(3, 28) = 2.884; p = 0.045). This is driven by the difference between the Old-Old drivers and the Young and Mid age groups, where the difference was around 35° in either direction. Range of vision was significantly negatively correlated with age (e.g. Card detection to the left: N = 32; r = -0.488; p = 0.005).

**Key result:** Neck flexibility (and resulting range of horizontal vision) reduces with age.
### 4.2.5 Visual closure

The visual closure test required participants to detect objects that were partially obscured by ‘snowy’ patterns. Participants were presented with seven such pictures and asked to identify the object (e.g. yacht). Results across age group are shown in Figure 4.7.

![Figure 4.7. Error bar chart showing mean scores on the visual closure test across age groups.](image)

Figure 4.7 shows that older participants were slightly worse at the visual closure test but an ANOVA test confirms that the difference between groups was not significant. Similarly, score on the visual closure test did not show a significant correlation with age.

**Key result:** Visual closure did not show a significant change across the age groups tested.
4.2.6  Choice reaction time

F shows the means of the recorded response reaction times (RRT); movement reaction time (MRT) and total reaction time (TRT) for each age group. These are respectively the time taken to start to move the finger from the rest position towards the target position; the time taken to complete that movement and the total of those two values.

![Error bar chart showing the mean RRT (response reaction time), MRT (movement reaction time) and TRT (total reaction time) for participants in the choice reaction time test across age groups.](image)

Figure 4.8 shows that Young and Mid age groups show similar response times in the CRT test. The Old-Young group shows slightly slower reactions in both RRT and MRT, whilst slowest response were observed for the Old-Old group. ANOVA tests confirm that differences in RRT \( F(3,28) = 6.118; p = 0.002 \), MRT \( F(3,28) = 7.239; p = 0.001 \) and TRT \( F(3,28) = 8.906; p < 0.001 \) are all significant across age groups. Post hoc comparisons show that the Old-Old group differs from the Young and Mid groups on all measures. The Old-Young group differs from the Young and Mid groups on MRT and TRT but not RRT, suggesting that it is the ability to make rapid co-ordinated movements that has begun to decline, not their mental processing capabilities. All three RT measures are highly positively correlated with age \((N = 32; r(RRT) = 0.608; r(MRT) = 0.653); r(TRT) = 0.684; p < 0.001\) in each case).

**Key result:** Choice reaction time performance decreases with age as a result of reduction in response time and movement time measures; however, the ability to make rapid co-ordinated movements appears to decline before mental processing capabilities.
4.3 Simulator driving results

4.3.1 Route 1: Pedestrian hazard

The route required the participants to pass a stationary truck parked in the driven lane. On the opposing carriageway was a bus stop. As the participants negotiated the lorry, a participant stepped out from behind the truck to cross the road towards the bus stop. The pedestrian was triggered to start walking when the driven vehicle was 48m from the pedestrian’s trajectory across the road.

4.3.1.1 Speed at trigger point

Participants’ choice of speed at the position when the pedestrian was triggered to start walking is a measure of their caution when approaching a parked vehicle and potential pedestrian hazard.

![Figure 4.9. Error bar chart showing mean speed at pedestrian trigger point across age groups.](image)

An ANOVA test reveals that there is a significant main effect of age group on speed (F(3, 26) = 3.19; p = 0.040) and that this driven by a significant difference between the Mid and Old-Old age groups. The results suggest that Old-Old drivers show the greatest caution by driving slowest whilst drivers in the Mid age group choose to drive fastest, perhaps based on a greater sense of confidence and greater annual mileage.

**Key result:** Older drivers showed slower speeds when negotiating a hazard.

4.3.1.2 Response to pedestrian

Not all participants stopped in response to the pedestrian – some swerved to avoid the pedestrian and continued driving. Two participants from each of the Young, Mid and Old-Old groups failed to stop and as did one participant from the Old-Young group. ANOVA tests were used to determine whether there were any differences in the characteristics of those that chose not continue driving rather than brake to a halt. These revealed that there was a highly significant difference in Violation scores from the DBQ test (F(1, 30) = 10.8; p = 0.003), whereby those failing to stop had much higher Violation scores.
Of those that did stop, it is possible to examine how quickly they applied the brakes after the pedestrian was triggered to move – measured by detecting when brake pedal pressure exceeded a threshold of 5 Newtons. Note that this measure is not a pure reaction time as the pedestrian appeared from behind the lorry shortly after being triggered to move. Results for this measure are shown in Figure 4.10.

![Figure 4.10. Error bar chart showing mean brake response time following pedestrian trigger across age groups.](image)

An ANOVA test reveals a significant main effect of age group on speed ($F(3, 19) = 3.58; p = 0.033$). Once again, this is driven by a significant difference between the Mid and Old-Old age groups; with the Mid drivers showing faster response times than the Old-Old drivers. Contrast sensitivity appears to play a role in participants’ brake response times as these were found to be positively correlated ($N = 24; r = 0.412; p = 0.046$).

The response times show the inverse result of the speed at trigger point measure showing that the Mid drivers respond faster, compensating somewhat for their faster speed choice. This can be investigated by examining reaction distance – the distance participants travelled after the trigger point before hitting the brakes; shown in Figure 4.11.

![Figure 4.11. Error bar chart showing mean brake reaction distance to pedestrian across age groups.](image)

Figure 4.11 shows that the distance travelled before participants applied the brakes in response to the pedestrian was broadly the same, confirmed by a non-significant ANOVA test ($p = 0.897$). For participants who stopped, it is possible to examine the safety
margin to the pedestrian when the vehicle came to a standstill. This is shown in Figure 4.12.

![Error bar chart showing mean safety margin to pedestrian across age groups.](image)

**Figure 4.12. Error bar chart showing mean safety margin to pedestrian across age groups.**

It can be seen that the Old-Old group achieved the greatest safety margin to the pedestrian despite having a slower brake response time. An ANOVA confirms that there is a main effect of age group ($F(3, 19) = 3.58; p = 0.033$) and this is driven by a significant difference between the Young and Old-Old groups. The higher safety margin achieved by the Old-Old group is likely to be due to the slower speeds attained on approach to the pedestrian. Despite having the highest speed on approach, it is not the Mid group that has smallest safety margin but the Young group. This reflects the faster response times achieved by the Mid group and possibly more effective braking.

**Key result:** Older drivers had slower reaction times to the appearance of a pedestrian but their lower speeds resulted in them having the largest safety margin to the pedestrian.
4.3.2 Routes 2(a) and 2(b): Crossroads

Routes 2(a) and 2(b) used the same road layout – a simple two-lane road with a crossroads. The participant was required to drive straight over at the crossroads but had to stop at the crossroads, where a ‘Stop’ sign was present. In 2(a), no traffic was present; in 2(b) a queue of cars travelled from right to left across the crossroads for which the participant had to wait before proceeding.

4.3.2.1 Speed on approach to the crossroads

Figure 4.13 shows the maximum speed attained by participants on approach to the crossing for the two routes.

![Error bar charts showing maximum speed attained on approach to the crossroads across age groups for routes 2(a) and 2(b).]

It can be seen that the maximum speeds on approach to the crossroads were broadly similar across age groups with the Mid group attaining the highest speeds and the older age groups tending to be slower. However, the differences between age groups were not significant for either route.

**Key result:** Drivers across age groups showed broadly similar speeds on approach to the crossroads.

4.3.2.2 Braking on approach to the crossroads

Figure 4.15 shows the distance from the stop line when participants first applied the brake pedal (above a threshold of 5 Newtons pedal force).
Older drivers and ‘failed to look’ crashes

Figure 4.14. Error bar charts showing mean distance to Stop line when brake first applied across age groups for routes 2(a) and 2(b).

Participants were broadly similar across age groups in the distance from the stop line at which they first applied the brake, confirmed by non-significant statistical comparisons.

Figure 4.15 shows the maximum brake force applied by participants on approach to the crossing for the two routes.

Figure 4.15. Error bar charts showing maximum brake force applied on approach to the crossroads across age groups for routes 2(a) and 2(b).

Maximum brake force observed on approach to the junction is similar across the two routes. For each route, it is drivers in the Young group that tend to show the lowest maximum braking effort with the least variability. An ANOVA test finds no significant main effect of age group in brake force application for either route. However, post-hoc tests show that drivers in the Young group showed significantly lower maximum brake force than Mid or Old-Old drivers on approach to the junction with traffic.

**Key result:** Drivers across age groups showed broadly similar braking on approach to the crossroads with no traffic. Younger drivers showed the lowest maximum brake force when traffic was present.
Figure 4.16 shows the distance to the stop line at which the simulator vehicle was stopped in readiness to negotiate the crossroads for the two routes.

**Figure 4.16.** Error bar charts showing mean distance to stop line when waiting to proceed at the crossroads across age groups for routes 2(a) and 2(b).

For this measure, it is clear that there is a tendency for older drivers to stop further from the stop line and with greater variability in stopping distance. A repeated measures ANOVA confirm that there is a significant main effect of age group ($F(3, 26) = 3.387; p = 0.033$). The significance of this result is driven by the difference between the performance of the Mid group and the Old-Old drivers across the two routes. This tendency is confirmed by a significant Pearson correlations between distance to stop line for Route 2(b) and both driver age and UFOV Selective attention (Driver age: $N = 30; r = 0.466; p = 0.010$; UFOV Selective attention: $N = 29; r = 0.368; p = 0.049$). These results suggest that older drivers either have poorer control in manoeuvring to the stop line or have more difficulty in perceiving the correct position at which to locate their vehicle, perhaps due to reduced useful field of view.

**Key result:** Drivers in the older age groups tended to stop further from the stop line at the crossroads, particularly when traffic was present.

### 4.3.2.3 Time stationary at crossroads

The presence of traffic at the crossroads in route 2(b) accounts for the overall differences observed between the routes in the time that participants spent stationary, waiting to proceed across the crossroads. Figure 4.17 shows the mean stationary time at the crossroads for the two routes across age groups.
Figure 4.17. Error bar charts showing mean time spent stationary at the crossroads across age groups for routes 2(a) and 2(b).

It can be seen that for route 2(a), there was very little difference between groups – all participants tended to stop for around 4-7 seconds before proceeding across the crossroads. Differences between groups were not significant.

For route 2(b) there is a tendency for older drivers to spend less time stationary; particularly the Old-Young group; reflected by a significant negative correlation between age and time spent stationary (N = 30; r = -0.467; p = 0.009). This reflects a tendency for the older drivers to keep rolling slowly approaching the crossroads. Having stopped further from the stop line, they would start to move towards the crossroads slowly waiting for the opportunity to cross the junction. The ANOVA comparing time spent stationary for route 2(b) produced a highly significant result (F(3, 26) = 8.29; p < 0.001), with the Old-Young group being different from all other groups.

**Key result:** Drivers in the Old-Young group spent less time stationary at the crossroads than the other age groups when traffic was present.

### 4.3.2.4 Acceleration away from the crossroads

The maximum acceleration achieved when pulling away from the crossroads was recorded to provide insight into whether there were differences in driving style across the age groups. Figure 4.18 shows the means of the maximum acceleration values for each participant across the age groups for the two routes.
Older drivers and ‘failed to look’ crashes

Figure 4.18. Error bar charts showing maximum acceleration observed pulling away from the crossroads across age groups for routes 2(a) and 2(b).

Results are broadly the same across the age groups for routes 2(a) and 2(b). There is a slight tendency for older drivers to show higher acceleration but no statistically significant differences were achieved.

Key result: Drivers across age groups did not differ in their acceleration away from the crossroads.

4.3.2.5 Visual behaviour

For routes 2(a) (crossroads; no traffic) and 2(b) (crossroads; with traffic) additional analysis of visual behaviour was conducted. Glance behaviour was recorded and compared between the age groups. A glance was defined as an eye movement (but not necessarily a neck movement) towards an object of interest. Figure 4.19 shows the mean number of glances to key targets in negotiating the crossroads – checking the rear-view mirror on approach; checking to the left and checking to the right.

Figure 4.19. Bar charts showing number of glances made to visual targets when negotiating the crossroads across age groups for routes 2(a) and 2(b).
For route 2(a), visual behaviour is broadly similar across the age groups – participants tended not to check their rear-view mirror on approach to the crossing and then made two or three glances in each direction before proceeding. A non-significant ANOVA test result confirms this similarity between age groups. For route 2(b), there is a tendency for older participants to make fewer glances to the right (the direction from which the traffic was travelling) before proceeding. Whilst the ANOVA test produces no significant main effect of age group; the post-hoc comparisons shows a significant difference (p = 0.031) for Young drivers vs. Old-Old drivers in the mean number of glances right before proceeding.

Visual behaviour was further characterised by examining the time spent looking left and right at the crossing before moving off. This is shown in Figure 4.20.

![Figure 4.20](image)

**Figure 4.20.** Error bar charts showing time spent looking left and right before proceeding at the crossroads across age groups for routes 2(a) and 2(b).

For route 2(a), all participants spent an approximately similar duration looking to the left and right before proceeding; the Old-Old participants showed the greatest variability in this duration. An ANOVA test confirms no significant differences between age groups. However, for route 2(b) – when traffic was present – some significant differences emerge. The Young and Mid age group participants spend considerably longer looking to the left and right than they did when there was no traffic present. However, Old-Young and Old-Old age groups have similar looking times in the no traffic and traffic conditions. This is confirmed by finding a significant main effect of age group on time spent looking left and right in the with traffic condition in an ANOVA test (F(3, 27) = 4.79; p = 0.008); post-hoc comparisons showing the results for the Young and Mid age groups both differed significantly from the Old-Young and Old-Old groups respectively.

**Key result:** Older drivers spent less time looking left and right when waiting at the crossroads when traffic was present.
4.3.3  **Route 3: Emerging hazard**

Routes 3 involved driving along a rural two-lane road, passing several side turnings on the left side of the road. At the third such turning, a vehicle unexpectedly emerged from the side road, turning right across the path of the driven vehicle. This was triggered in the expectation that participants would need to make a response in order to avoid a collision.

4.3.3.1  **Speed on approach**

Figure 4.21 shows the mean and maximum speeds observed of participants on approach to the hazard.

![Mean speed - Maximum speed](Image)

**Figure 4.21. Error bar charts showing mean and maximum speeds observed when approaching the emerging hazard across age groups.**

Figure 4.21 shows that younger participants tended to adopt faster speeds and older participants tended to adopt lower speeds, with the mean and maximum speeds differing by 9mph and 11mph between the youngest and eldest age groups. The figure also suggests that the Old-Old participants showed the greatest inter-participant variability in these measures, indicated by having the largest error bars on the mean value. ANOVA tests show that there was a significant effect of age group on mean speed ($F(3, 26) = 4.87; p = 0.021$) and maximum speed ($F(3, 26) = 3.58; p = 0.027$); Old-Old participants were significantly slower than the Young or Mid group on both measures.

**Key result:** Older drivers tended to drive slower on a rural road with side turnings.

4.3.3.2  **Response to emerging hazard**

Most participants had to brake in response to the movement of the vehicle. Figure 4.22 shows participants’ mean brake reaction time – the time taken after the triggering of the emerging vehicle for the participants to achieve 5 Newtons brake pedal pressure.
Figure 4.22 shows that reaction times were similar across the age groups with the Young group showing the fastest reaction times – although differences did not reach statistical significance.

The combination of slower speeds and similar reaction times suggest that older drivers are well placed to respond to such emerging hazards.

**Key result:** Drivers across age groups showed similar brake reaction times in response to a vehicle suddenly emerging from a side turning.
4.3.4 Route 4: Braking vehicle

In route 4, participants were required to follow a lead vehicle along a two-lane rural road. After a short time, the lead vehicle applied its brakes unexpectedly.

4.3.4.1 Headway distances

Figure 4.23 shows the mean and minimum headway distances (distance in metres between the back of the lead vehicle and the front of the driven vehicle) observed when following the lead vehicle before the braking manoeuvre across the age groups.

![Error bar charts showing mean and minimum headway distances observed following the lead vehicle across age groups.](Image)

It can be seen that the Old-Old participants seem to choose a longer following distance than the other age groups. Differences in both measures are statistically significant on ANOVA tests (Mean headway: $F(3, 27) = 3.451; p = 0.030$; Minimum headway: $F(3, 27) = 3.650; p = 0.025$), with the Old-Old group differing from each of the other age categories on both measures.

Figure 4.24 shows the standard deviation of headway in the run-up to the braking manoeuvre.

![Error bar chart showing standard deviation of headway observed following the lead vehicle across age groups.](Image)
Although there were differences between the Old-Old group and other participants in following distance, their ability to keep at a steady distance from the lead vehicle is similar, as shown by the similar standard deviations of headway observed across age groups.

**Key result:** Drivers in the Old-Old group tended to keep longer but consistent distances behind a lead vehicle.

### 4.3.4.2 Response to braking vehicle

Inspection of the data showed that two drivers, both in the Old-Old age group, were following at more than 200m when the lead vehicle was triggered to slow down. The speed adopted by these participants at this time (around 25mph (11.2m/s)), gave them ample time to respond and so their responses were qualitatively and quantitatively different to those of other participants. The data for these two participants has therefore been excluded from this section.

Figure 4.25 shows participants’ mean brake reaction time in response to the deceleration of the lead vehicle across age groups.

![Figure 4.25. Error bar chart showing brake reaction time to the braking vehicle across age groups.](image)

As with the emerging hazard, it can be seen that all participants show broadly similar reaction times in response to the braking of the lead vehicle. Despite this, it was found that brake reaction times were positively correlated with contrast sensitivity (N = 25; r = 0.403; p = 0.046).

**Key result:** Drivers across age groups showed similar brake reaction times in response to a lead vehicle braking unexpectedly.
**4.3.5 Route 5: Motorway driving**

In route 5, participants drove on a standard, three-lane (plus hard shoulder) motorway for around five minutes. After a period of acceleration, they met other traffic vehicles before all three lanes were brought to a halt in a traffic jam. This concluded the test route.

### 4.3.5.1 Speed

Figure 4.26 shows participants’ mean speed on the motorway route.

![Figure 4.26](image)

**Figure 4.26. Error bar chart showing mean speed on the motorway route across age groups.**

Figure 4.26 shows the expected pattern of speeds with older drivers tending to adopt slower speeds than younger drivers. The Old-Old group also show greater inter-individual differences in driving speeds as shown by the large 95% confidence interval on the mean speed value. An ANOVA test confirmed that there was a significant difference between age groups ($F(3, 28) = 3.957; p = 0.018$), with post-hoc comparisons indicating that this result was due to the difference between Young and Old-Old participants ($p = 0.002$). Standard deviation of speed – the degree to which speed varied when driving did not differ significantly across age groups suggesting that despite differences in speed between groups, the consistency of cruising speed adopted by individuals within each group did not differ.

**Key result:** Older drivers tended to drive slower on motorways.

### 4.3.5.2 Lane choice

Schlag (1993) found that younger drivers were more comfortable making lane-change manoeuvres so it was possible that we may have seen fewer lane changes by older drivers in the motorway route. However, the number of lane changes observed within the route was typically low with mean values of the number of lane changes by drivers within each age group around 2.5-3.2 and difference did not reach statistical significance.

In addition to lane changes, lane occupancy was analysed. Figure 4.27 shows the mean proportion of time that participants in each age group spent in each of the three lanes of the motorway over the course of the drive.
Figure 4.27. Proportion of time spent in each lane of the motorway across age groups

Figure 4.27 shows that there is a progressively increasing tendency for participants to spend time in the middle lane as the age groups get older – until the final Old-Old age group which has similar occupancy of lanes 1 and 2. It appears that younger drivers are more willing to drive in lane 1 of the motorway than their elder counterparts.

**Key result:** Drivers in the Old-Young group showed a greater tendency to use the middle lane when driving on the motorway.
4.3.5.3  Visual behaviour

Participants’ visual behaviour was analysed by assessing the number of glances to the rear-view, nearside and offside mirrors when cruising on the motorway. Figure 4.28 shows the mean glance frequency to each mirror across the age groups. When considering this analysis, it should be borne in mind that all age groups tended to make similar numbers of lane changes within this scenario (see 4.3.5.2).

![Figure 4.28](image)

Figure 4.28. Bar charts showing number of glances made to the mirrors when cruising on the motorway across age groups.

Figure 4.28 shows that the Young and Mid age groups have a similar pattern of mirror viewing, whilst the Old-Young group show the highest frequency of glances to all mirrors. Conversely, the Old-Old group have a notably different pattern of mirror use, taking many fewer glances to the rear-view mirror than other groups. An ANOVA test confirms this difference as significant ($F(3, 28) = 3.693; p = 0.023$), with post-hoc comparisons showing that the Old-Old group had significantly fewer glances to the rear-view mirror than all other age groups ($p < 0.05$ in each case).

**Key result:** Drivers in the Old-Old group made many fewer glances to the rear-view mirror when driving on the motorway.
4.3.6 Situational awareness

In each of routes 1, 2(b) and 3, participants were asked a situational awareness question relating to details about the scenario they had just experienced. Figure 4.29 shows the mean number of incorrect answers given by participants in across age groups.

![Bar chart showing mean number of wrong answers by age group](image)

**Figure 4.29. Bar chart to show the mean number of wrong answers given by participants to the three situational awareness questions across age groups.**

Figure 4.29 shows that the youngest age group made the fewest errors. Older groups made more errors with the Old-Young category performing worst. An ANOVA test on these data produced no significant main effect of age group ($p = 0.164$) although the post-hoc comparison of Young and Old-Young scores did reach significance ($p = 0.030$).

**Key result:** Younger drivers made the fewest errors on questions of situational awareness but differences did not reach statistical significance.
5 Summary of key results

5.1 Questionnaires

Driver behaviour questionnaire scores indicate that older drivers are less likely to engage in driving violations whilst younger drivers show more variable DBQ Violation scores.

Driver attitude questionnaire scores indicate that older drivers have safer and more consistent attitudes towards close following and dangerous overtaking.

5.2 Vision and response tests

Visual acuity tends to decrease with age.

Useful field of view declines with age although the magnitude of the decline varies suggesting large individual differences.

Contrast sensitivity thresholds decline with age; although again the variability increases with age suggesting large individual differences.

Neck flexibility (and resulting range of horizontal vision) reduces with age.

Visual closure did not show a significant change across the age groups tested.

Choice reaction time performance decreases with age as a result of reduction in response time and movement time measures; however, the ability to make rapid coordinated movements appears to decline before mental processing capabilities.

5.3 Simulator driving results

Older drivers showed slower speeds when negotiating a hazard.

Older drivers had slower reaction times to the appearance of a pedestrian but their lower speeds resulted in them having the largest safety margin to the pedestrian.

Drivers across age groups showed broadly similar speeds on approach to the crossroads.

Drivers across age groups showed broadly similar braking on approach to the crossroads with no traffic. Younger drivers showed the lowest maximum brake force when traffic was present.

Drivers in the older age groups tended to stop further from the stop line at the crossroads, particularly when traffic was present.

Drivers in the Old-Young group spent less time stationary at the crossroads than the other age groups when traffic was present.

Drivers across age groups did not differ in their acceleration away from the crossroads.

Older drivers spent less time looking left and right when waiting at the crossroads when traffic was present.

Older drivers tended to drive slower on a rural road with side turnings.

Drivers across age groups showed similar brake reaction times in response to a vehicle suddenly emerging from a side turning.
Drivers in the Old-Old group tended to keep longer but consistent distances behind a lead vehicle.

Drivers across age groups showed similar brake reaction times in response to a lead vehicle braking unexpectedly.

Older drivers tended to drive slower on motorways.

Drivers in the Old-Young group showed a greater tendency to use the middle lane when driving on the motorway.

Drivers in the Old-Old group made many fewer glances to the rear-view mirror when driving on the motorway.

Younger drivers made the fewest errors on questions of situational awareness but differences did not reach statistical significance.
6 Discussion

This study has investigated how drivers’ visuo-cognition changes with age and how its effect performance on some specific driving tasks using TRL’s driving simulator, DigiCar.

6.1 Older drivers and attitudes to driving

Participants completed the driver behaviour and driver attitude questionnaires (DBQ and DAQ respectively). Results for the DBQ showed that there was a tendency for older drivers to show lower scores on the DBQ Violations subscale, indicating that they are less likely to engage in driving violations. Similarly, results for the DAQ indicated that older drivers showed safe attitudes to close following and dangerous overtaking. This is consistent with typical findings around older drivers’ attitudes to driving (Angle, Buckley, Fearn & Goddard, 2007) and suggests that older drivers’ apparent increased risk in ‘failed to look’ accidents is not due to a reckless mentality when driving.

6.2 Older drivers and visuo-cognitive tests

The results from the visuo-cognitive tests show expected declines in capabilities with age. All participants showed visual acuity that was sufficient to pass the number-plate test that forms part of the UK practical driving test. However, there was a tendency for Older participants to show poorer visual acuity. The UFOV test indicated that older participants had a more restricted useful field of view in both divided and selective attention. Owsley et al. (1998) showed that UFOV was associated with increased future crash involvement so it was important to include this measure within this study. Contrast sensitivity showed a marked decline with age. Marottoli (1988) found that a severe reduction in contrast sensitivity was associated with increased crash risk. An apparent reduction in neck flexibility resulted in a reduced range of horizontal vision for older drivers. This suggests that they would be able to cover less of the visual field when turning if they choose to make over-the-shoulder checks when pulling into traffic or changing lanes on the motorway. This highlights the importance of correct rear-view and wing mirror adjustment and use by older drivers. Finally, older drivers showed slower reaction times as could be predicted based on previous research (e.g. Anstey et al., 2012). A driver with slower reaction times is less able to respond rapidly to unexpected events that may occur whilst driving.

In the various visual tests, it was notable that results for older and particularly the Old-Old group had the largest error bars (which demarcated the 95% confidence interval on the mean). This suggests that there was significant inter-participant variation within the Old-Old age group, lending weight to the argument that there is distinct heterogeneity in the ageing process between individuals. This means that judgements of driving ability based solely on age risk disadvantaging the proportion of older drivers who remain very capable into old age. However, it is important that this message is communicated appropriately. Publicising that there is a proportion of older drivers whose capabilities decline at a slower rate risks widespread adoption of the possibly erroneous belief that ‘it is not happening to me’. Such an older driver may therefore choose not to take any steps to address the challenges they face. Consequently, it is important that older drivers can receive clear and impartial advice about concerns they may have in relation to any changes they may have experienced in their vision and/or abilities to maintain safe control of their vehicle.
Whilst this pattern of results was entirely predictable based on previous research (and reviewed herein), it was important to confirm that the participants involved in this study displayed the expected pattern of visual performance in order to support interpretation of driving performance observed in the simulator study.

6.3 Older drivers and simulator driving tests

Participants completed six different driving scenarios in the simulator.

6.3.1 Route 1: Pedestrian hazard

In route 1, a pedestrian walked from behind a parked vehicle. It was clear that older drivers tended to take a more cautious approach, adopting slower speeds when negotiating the parked vehicle. Despite the Old-Old participants having significantly slower reaction times, their slower speeds resulted in them having the greatest safety margin to the pedestrian. This suggests that the older participants were aware of the slowing of their reactions or difficulty in detecting hazards due to poorer contrast sensitivity and adapted their driving style so that they were able to make timely responses to unexpected hazards. There was a slight tendency for drivers in the Mid age group (who cover the highest annual mileage) to show the fastest response times to the appearance of the pedestrian – possibly associated with their greater experience or their tendency to adopt higher speeds on approach to the pedestrian (and therefore needed to make a swifter response).

A small number of participants chose to swerve around the pedestrian rather than bring their vehicle to a halt. It was notable that the participants who chose not to stop tended to show higher scores on the DBQ Violation subscale; a trait associated with younger drivers.

6.3.2 Routes 2(a) and 2(b): Crossroads

The results for the crossroads routes suggested that the older drivers found it more difficult to place their vehicle accurately at the stop line, particularly when other traffic was present. This seems to be associated a reduced useful field of view. The position older drivers adopted at the crossroads made it harder to see approaching traffic and increased the time required to complete the manoeuvre of crossing the junction. It was also apparent that participants in the older age groups spent less time looking to the left and right than the younger groups when traffic was present at the crossroads. The combination of poor placement at the junction and less time spent looking for approaching hazards suggests that there are measurable changes in behaviour that occur for older drivers that would place them at an increased risk of collision at junctions. This offers some explanation as to why older drivers are over-represented in accidents where the item ‘failed to look’ has been identified as a contributory factor and may offer insights into how older drivers may be trained or how support technologies may be targeted in order to reduce this risk.

6.3.3 Route 3: Emerging vehicle

In the emerging vehicle scenario, participants drove on a rural road past side turnings to their left. At the third such turning, a vehicle emerged suddenly. On approach to this hazard, there was a clear negative correlation between speed choice and age – older drivers tended to drive more slowly, with the eldest group more than 10mph slower. This
Older drivers and ‘failed to look’ crashes

suggests greater caution by the older drivers and perhaps adaptation to the slowing of their reactions. Brake reaction time results showed that in fact, drivers across all age groups showed similar reaction times. Consequently, the older drivers, travelling at slower speeds were better placed to respond to this hazard.

6.3.4 Route 4: Braking vehicle

In following the lead vehicle in this scenario, it was apparent that participants in the eldest age category kept the furthest distance from the lead vehicle. However, their ability to maintain a consistent distance behind the lead vehicle did not differ from that of the other age groups. This suggests that they simply preferred to keep a larger headway to the lead vehicle. When the lead vehicle applied its brakes unexpectedly, participants response times pressing the brake were broadly similar such that all participants were able to stop with sufficient safety margin to the lead vehicle.

6.3.5 Route 5: Motorway driving

In this scenario, participants simply drove on a standard UK motorway with light traffic before reaching heavier traffic and eventually coming to a halt in a traffic jam. As could be expected, older participants tended to adopt a lower mean speed on the motorway, significantly lower than the youngest participants. Although participants across age groups tended to make a similar number of lane changes, there was an apparent tendency for the Old-Young participants to spend a significantly higher proportion of their time driving in lane 2 (the middle lane). Driving in the middle lane can be considered a conservative driving style since it requires the participant to make fewer lane changes. However, this is addressed directly in the UK Highway Code (2007) by rules 137 and 264:

137: On a two-lane dual carriageway you should stay in the left-hand lane. Use the right-hand lane for overtaking or turning right. After overtaking, move back to the left-hand lane when it is safe to do so.

264: You should always drive in the left-hand lane when the road ahead is clear. If you are overtaking a number of slower-moving vehicles, you should return to the left-hand lane as soon as you are safely past...

Remaining in the middle lane when the left lane is available as an offence punishable by a fine and penalty points so apart from the safety and network efficiency benefits of keeping left, it is advisable that drivers abide by these rules.

Finally, participants in the Old-Old group showed a much lower glance frequency to the rear-view mirror than the other age groups when driving on the motorway. This means they have poorer awareness of the traffic situation around them and, as with the crossroads scenario, have poorer information on which to base their decision should they need to change lanes. This result may be related to the finding that the participants in the Old-Old group tended to conduct the lowest proportion of their driving on motorways and so may be less accustomed to the greater requirement to scan the mirrors.

6.3.6 Situational awareness

The young participants made the fewest errors when asked about details of the driving scenarios, although the statistical tests on this measure did not reach significance. It would have been interesting to investigate this facet of performance more thoroughly.
but care was taken not to cause drivers to adjust their driving behaviour such that they were always trying to observe details of the route (rather than applying their normal driving techniques). This is an area that would benefit from further research in potential future studies.

6.4 Recommendations

The results of this study suggest the following recommendations:

There were some specific differences in the behaviour of the Old-Old group in terms of their positioning and visual scanning at junctions.

- Driver training and/or driver support systems could be developed with the aim of supporting older drivers in this task. These could assist in positioning the vehicle relative to the junction markings to ensure the driver gets the best view of any approaching traffic and provide visual, auditory and/or tactile warnings about approaching traffic to support the decision about when to proceed.

- A controlled before-after evaluation of the effectiveness of a technology and/or training intervention aimed at improving older driver behaviour in relation to positioning and visual scanning at junctions might demonstrate that with suitable support many drivers can remain independently mobile for longer into older age.

Older drivers, particularly the Old-Old group showed the greatest variability in numerous measures of vision and driving performance.

- Self- and/or independent assessment of driving ability should play a vital role in continuing driving into older age. Older drivers should feel that they can voice any concerns about their driving in the knowledge that every effort will be made to support their desire to remain safely and independently mobile.

Older drivers showed the safest attitudes towards driving.

- Young drivers could benefit from understanding how attitudes to driving change into older age both to improve their own subjective feelings towards driving and to gain insight into why older road users may behave in a manner that is different to their expectations.

6.5 Limitations and further work

This study has used TRL’s driving simulator DigiCar as a tool to investigate the driving performance of participants. Whilst studies have sought to validate the simulator as a tool for such investigations (e.g. Diels, Robbins & Reed, 2012), the simulator does not provide participants’ with an experience that could readily be mistaken for reality. Consequently, the differences between the simulated reality presented in the simulator and actual reality experienced on real roads may play a role in the differences in driving performance identified in this study. For example, projectors and display screens cannot produce the brightness and contrast that would be experienced by a driver in typical daylight driving. However, the validation studies provide some assurance that although the absolute changes in performance observed in the simulator may not be correct, the relative differences (i.e. the direction of the changes) are representative of those that would be observed in similar situations in the real world. Although the simulator provides a safe environment in which to examine risky driving situations, it would be beneficial to
Older drivers and ‘failed to look’ crashes consider real world, naturalistic studies that examined the actual behaviour of older and younger drivers in similar critical situations.

A study such as this must balance the depth of examination into participant behaviour and attitudes with breadth, in terms of the number of participants recruited to take part, within the available resources. This study used a small number of participants within each age group. The strength of the results could be improved by extending this sample and possibly considering other driving situations. These could include more visually challenging driving environments such as driving at night or in poor weather conditions or more cognitively demanding scenarios such as those involving navigation or more complex traffic interactions. It would be useful to include scenarios where critical situation awareness could be investigated more thoroughly.

This study used drivers with no declared visual problems such as cataracts or age-related macular degeneration. It would be of interest to run a follow-up study that investigated how drivers with such visual deficits perform in the test scenarios. This could be run in association with a medication programme to evaluate whether successful treatment of such conditions could allow drivers to remain safe on the roads.

Participants recruited for the study had previous experience of driving TRL’s simulator; an approach not uncommon in such studies. This was done to minimise the risk that the novelty of driving the simulator would influence behaviour in the short (less than five minutes of driving) simulated scenarios used in the study. This is less important in for example, motorway driving studies, where we are interested in overall driving behaviour over a long period of time rather than specific responses in safety critical situations. For the study reported here, we wanted to be confident that participants felt comfortable controlling the simulator and that their driving behaviour, particularly in the safety critical scenarios, was therefore representative of that they would produce in the real world.

7 Conclusion

This study has shown that older drivers appear to be aware that the age-related decline in their visual, cognitive and physical abilities affects their driving. They appear to attempt to compensate for this by adopting slower speeds and longer following distances. Older drivers also showed safer attitudes to driving as shown by their DBQ and DAQ scores. However, this study was conceived to understand why older drivers are over-represented in ‘failed to look’ accidents and a number of interesting themes emerged.

Critically, when negotiating a crossroads, older drivers positioned their vehicle poorly such that it was harder to see other traffic before proceeding across the junction. They also spent less time looking left and right before taking the decision to move off. It was suggested that this could be habitual or a result of slower movement in turning left and right to view the scene. However, poor positioning and less time performing visual checks may be the key reasons why older drivers have difficulties at junctions, resulting in a higher risk of accidents classified as having ‘failed to look’ as a contributory factor.

Similarly, it was observed that when driving on the motorway, the oldest drivers made fewer glances to the rear-view mirror. This means they are likely to have poorer situational awareness – a lesser appreciation of what hazards may be in their vicinity and how the driving situation may develop. This reduced situational awareness may also
result in collisions where it could be surmised that the driver had ‘failed to look’ before acting.

These two results highlight an interesting contradiction in that, in these specific driving tasks, despite having better attitudes to driving, it is the older drivers who showed the least safe approach to the driving tasks. This emphasises that the changes in performance that result in increased risk are not deliberate but arise through the various changes that occur through the ageing process.

In concluding this study, it should be noted that in most of the test results, the largest inter-participant variability was observed in the eldest age group. Furthermore, individuals within the eldest participant group demonstrated performance in the simulated driving scenarios similar to that of participants in the younger groups\(^1\). This suggests that the declines in vision, cognitive and motor function and the resultant changes in driving performance are not uniform across all individuals as they age and highlights the challenge in making any judgements about ability to drive based solely on age or any other single measure.

This study has provided a small but revealing snapshot into age-related differences in visuo-cognitive ability and driving behaviour that provides insight into why older drivers are over-represented in failed to look accidents.

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\(^1\) For example, although participant 28 (female, age: 78 years) had acuity, contrast sensitivity and UFOV scores that were representative of her age group yet her brake response times in Routes 1, 3 and 4 and stopping position in Routes 2(a) and 2(b) was within the 95% confidence interval of the younger age groups.
8 Acknowledgements

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9 References


Older drivers and ‘failed to look’ crashes


Why do older drivers have more ‘failed to look’ crashes? A simulator based study

With an increase in life expectancy comes an increase in the proportion of older drivers. Various crash studies and surveys have shown that older drivers are particularly over-represented in crashes at intersections, where typically the older driver turns against oncoming traffic with right of way on the main road. This study aimed to investigate the correlation between ‘failed to look’ errors, which previous studies have identified as a key factor in crashes involving older drivers, and visuo-cognitive deficits. The first phase of the study reviewed relevant literature to provide a background to the cognitive and visual measures used. The second phase of the study included simulator and laboratory based tests of visual and cognitive performance, in general and when driving. The study demonstrated that older drivers tend to have reduced visual capabilities. In many respects, their experience enables them to compensate for these deficiencies. However, some specific changes in behaviour were observed that seem strongly linked to the tendency for older drivers to be over-represented in ‘failed to look’ accidents. Support for older drivers to improve performance through training and/or support technologies may help to tackle this problem, although any intervention would require evaluation and validation of effectiveness.

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