Examining the role of cognition in driving: Comparisons between driver groups and the development of the Maynooth On-Road Driving Assessment

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Abstract

Driving is a complex task which requires the interaction of multiple higher level cognitive skills, each of which can be affected by experience, age, and cognitive impairment. Assessing at-risk drivers can be done via pre-screening tests and on-road measures to identify any decrements in fitness to drive. This thesis found that experienced drivers responded more slowly (Mean RT = 799.97ms, $p = .03$) on a measure of executive function (Stroop Colour Word test) and reported greater confidence in their driving ability (Mean rating = 7.7, $p < .005$) than novice drivers. Older adults were found to have longer response times in a measure of attention (Attentional Network Task, $p = .004$), and of executive function (Stroop Colour Word test, $p < .005$), and performed less well in an off-road driving measure (Useful Field of View subtest 3, $p = .001$) than younger adults. These findings demonstrate significant differences in some cognitive abilities as a result of driving experience and age; additionally, we found that the Stroop Colour Word test should be considered as a more sensitive measure of executive function in pre-screening driving batteries. Finally, this thesis developed a standardised on-road driving test (Maynooth On-Road Driving Assessment [Morda]) with good inter-rater reliability overall (Cronbach's $\alpha = .97$) and on four of the five cognitive measures (attention, planning, decision making, and memory). These results and the development of the Maynooth On-Road Driving Assessment further the goal of integrating cognitive assessment with on-road driving tests in a standardised measure of at-risk drivers in Ireland.

Chapter 1

General Introduction

Ireland's population of older adults is growing rapidly. According to the 2006 census, nearly half a million adults over the age of 65 were living in Ireland, and statistics from 2009 showed that 9% of these were in gainful employment. Preliminary analyses of the 2016 census estimate that older adults comprise 13% of the country's current population, with that number expected to grow to 28% by 2041. Ireland's population of older adults is predicted to triple in the next 30 years, including a five-fold increase in the number of people older than 85 (Centre for Ageing Research and Design [CARDI], 2010). This population growth is not limited to Ireland; it is estimated that around the world, approximately one million people turn 60 every month (McGill, 2010). With advances in technology and modern medicine, society has seen life expectancies rise dramatically. In the UK, the number of people aged 100 and above has increased by 65% over the last 15 years (Office for National Statistics, 2016). Older adults have historically been a minority group within the larger population; that this may be set to change over the coming decades is unprecedented. Given this, it is becoming increasingly important to further our understanding of the changes and challenges associated with aging. Organizations like the Health Research Board, the Centre for Ageing Research and Design (CARDI), and Technology Research for Independent Living (TRIL) indicate a movement towards Irish research in this area.

It is well known that maintaining a good quality of life (QoL) is vital to supporting the older adult within the community (CARDI, 2010; Fan, McCandliss, Sommer, Raz, & Posner, 2002). As people enter old age, the likelihood of developing life-limiting illnesses increases, general health gradually declines, social networks may shrink, and income generation becomes more difficult (Netuveli, Wiggins, Hildon, Montgomery, & Blane, 2005). Simultaneously, this group is retiring earlier, consuming more, and traveling further than in previous decades (Banister & Bowling, 2004). In order to maintain QoL, it is imperative that older adults can continue to access services, retain their mobility, and be independent for as long as is practicable (CARDI, 2010).

Driving is an increasingly common activity, particularly in the western world. Statistics from the Road Safety Authority show that there were nearly 3 million licensed drivers in Ireland at the end of 2015 (RSA). According to the European Commission, a quarter of all drivers in the EU will be aged 65 or over by 2030 (OECD, 2001). More than half of all new cars purchased in Europe are done so by people over the age of 50 (Banister & Bowling, 2004). Men in their early 60s are driving more than the average for the entire population, while the elderly in general are driving further and more frequently than this group did 15 years ago (Office for National Statistics, 2016). In the coming decades, older drivers will transition from a minority population to one of the largest driving subgroups on the roads (Connell, Harmon, Janevic, & Kostyniuk, 2012; Freeman, Gange, Munoz, & West, 2006). This will inevitably have an impact on driving dynamics; not only will more older adults be driving, but younger adults will have to modify their driving styles in order to accommodate this (Hakamies-Blomqvist & Wahlstrom, 1998; Connell et al., 2012).

Maintaining the ability to drive is important for the aging adult. A sense of loss of independence accompanies driving cessation; more than 60% of the trips taken by older adults are made alone (Adler & Rottunda, 2006). The loss of a driver’s license has a profound effect on the mobility and QoL of the older adult: maintaining the ability to drive is linked with both a sense of autonomy and self-esteem (Adler & Rottunda, 2006). Studies have even found that the physical health and wellbeing of the older adult may be directly influenced by driving, with general health actually declining more steeply with driving cessation (Edwards, Lunsman, Perkins, Rebok, & Roth, 2009). In addition to the above considerations, older adults report more stress associated with and frequent avoidance of certain traffic situations (Hakamies-Blomqvist & Wahlstrom, 1998). An inability to drive leads to a reduction in the capacity to complete the activities of daily living, with adult children reporting concerns that they have to take on much of the transportation responsibility for their elderly parents (Connell et al., 2012). A study by Freeman et al. (2006) found that cessation of driving is an independent risk factor for older adults entering long-term care, as was not having a driver living in the household. Ceasing to drive creates more interference with social opportunities, where older adults are less capable of visiting family and friends. When driving stops, the likelihood of depression and social isolation increase, and this is not remediated by public transport options (Edwards et al., 2009; Ragland, Satariano, & MacLeod, 2005).

Cognition and driving

The impact that driving has on the standard of living of the older adult clearly indicates that a thorough understanding of this population of drivers is warranted. The question then arises as to why older adults would choose to cease driving if it is so important to their wellbeing. There are physical considerations of the older adult which may impede driving, such as complications from illnesses, impaired vision, and general decline of physical mobility (Edwards et al., 2009). However, these can often be remediated by vehicle modifications which may help to compensate, such as enlarged dashboard displays, addition of a steering wheel knob, or hand-operated braking systems (Singh, Pentland, Hunter, & Provan, 2006). Multiple other biological factors are also associated with old age, including changes in the amount of white matter in the brain, atrophy of certain areas of the brain, and a decrease in neurotransmitters (Buckner, 2004). There are also marked increases in the likelihood of developing neurodegenerative disorders, such as Parkinson's and Alzheimer's disease (Buckner, 2004). These cognitive changes are less obvious and potentially more significant in terms of declining driving ability.

Older adults demonstrate reduced performance in the areas of attention, memory, and the learning of new things, yet simultaneously this population may also have improved performances in other cognitive areas, such as verbal knowledge (Alzheimer's Disease Education and Referral Center [ADEAR], 2008). These considerations can have a direct impact on driving ability; motor vehicle accidents are the leading cause of death of people aged 56-71 in the USA (Fawcett, Risko, & Kingstone, 2015). While aging is generally associated with declining health and cognitive ability which may, in turn, impact on driving, it is neither fair nor appropriate to restrict driving based on age alone (O'Connor, Kapust, & Hollis, 2008). License restrictions and renewal policies based on age alone do not decrease the number of fatalities associated with road traffic accidents in this population (Hakamies-Blomqvist & Wahlstrom, 1998). Indeed, while the crash rates among older adults are reported to be higher than other age groups (Richardson & Marottoli, 2003), a study by Langford, Methorst, and Hakamies—Blomqvist (2006) posits that older adults may be safer drivers when compared using annual driving distances.

Health and cognitive declines are associated with aging but they are not uniform across older adults (O'Connor et al., 2008); even these changes may not be significant enough to warrant driving cessation, and it is therefore necessary to be able to measure those changes on a case by case basis (Korner-Bitensky, Gelinas, Man-Son-Hing, & Marshall, 2005; Lee, Cameron, & Lee, 2003). Furthermore, it has been repeatedly demonstrated that driving experience improves driving ability, and so the declining older adult may still be a safe and competent driver for years into old age (McKnight & McKnight, 2003). Driving itself is a complex task which draws on multiple cognitive processes, many of which may become impaired as a byproduct of normal aging (Bowers et al., 2013). Because of this, the most appropriate way to keep older adults behind the wheel is to be able to identify which changes are most predictive of safe driving and to develop a reliable and valid way to measure those changes.

Multiple types of attention are necessary for maintaining safe driving, and many aspects of attention become automatic over time (Fawcett et al., 2015). Focused attention allows drivers to react to unpredictable events; divided and selective attention enable drivers to ignore distractors and attend to hazardous stimuli; and sustained attention is required to keep drivers engaged with the driving task (Roca, Castro, Lopez-Ramon, & Lupianez, 2011). Driver distraction and lapses in attention are thought to be closely linked to motor vehicle accidents (Roca, Lupianez, Lopez-Ramon, & Castro, 2013a), with greater inattention found in novice as compared to experienced drivers (McKnight & McKnight, 2003).A study by Clarke, Ward, Bartle, & Truman (2010) cites problems with attention as one of the primary causes of risk in older drivers Independent attentional networks contribute differently to the task of driving, and there are multiple tests devised to measure both their individual and interactive qualities (Roca, Crundall, Moreno-Rios, Castro, & Lupianez, 2013b). The attentional orienting network allows for the selection of appropriate information from the environment and allocation of focus to the most salient objects, in particular those stimuli which highlight a hazard (e.g. a stopped bus indicates that pedestrians may cross the road). The attentional alerting network heightens the sensitivity of the individual to impending stimuli; this network is comprised of phasic alertness, whereby the person is more ready to react following a warning stimulus, and tonic alertness, which comprises of vigilance and the ability to maintain attention over time (Roca et al., 2013a). Executive attention enables the driver to monitor multiple aspects of a complex traffic environment while selecting which stimuli to focus on, thus ignoring competing distractors (Weaver, Bedard, McAuliffe, & Parkkari, 2009). Visual attention dictates which information is relevant and which is excluded in detailed visual scenes (Squire, 2009); problems in visual attention have been linked with impaired driving performance (Mazer, Korner-Bitensky, & Sofer, 1998).

Other aspects of cognition are also important to driving, including executive function. Planning, decision making, self-regulation, and mental flexibility are all aspects of executive function which have been linked with the complex task of driving (Asimakopulos, Boychuck, Sondergaard, Poulin, Menard, & Korner-Bitensky, 2011). Memory is important to driving, with road users having to recall directions, how to maneuver appropriately, the rules of the road, meanings of road signs, and so forth. Executive function and memory can be severely impaired by illnesses and neurodegenerative disorders commonly associated with aging, including dementia and stroke (Mazer et al., 1998; Buckner, 2004). Given the importance of cognition in driving, the knowledge of its decline in normal aging, and the importance of driving to the older adult, the question then arises as to how to best measure these changes in a reliable and valid way as part of driving behavior.

Effects of Driving Experience

Statistics show that the rates of motor vehicle accidents are highest among novice drivers, particularly in the first year of driving. Novice drivers demonstrate errors in attention, problems with visual searching, poor speed maintenance, and less skill at recognizing hazards than their more experienced counterparts (Mayhew, Simpson, & Pak, 2003). A study by McKnight & McKnight (2003) found that the decreasing rates of motor vehicle accidents in the first year of driving are similar across drivers who were first licensed at 16 versus at 18 years old, which indicates that experience rather than age may be more significant in driving ability. That study also found deficiencies of attention to be a contributing factor in 23% of crashes among novice drivers. Experienced drivers pay more attention to dangerous hazards than novice drivers (Owens, 2009); demonstrate different scanning patterns of the traffic environment compared to novices (Underwood, 2003); and take longer to respond to risks in more difficult traffic scenarios than novices (Owens, 2009). There are measurable differences in attention which may partially account for the lower crash rates among experienced drivers. Given that the majority of novice drivers are young when attaining their first driving license, research has been somewhat restricted in determining whether age or experience is more relevant to reducing road traffic accidents. Novice drivers are at a greater risk of causing a motor vehicle accident in their first year of driving (Owens, 2009) while risky driving styles have been shown to increase in the first three years of driving, as well as driving errors and traffic violations (Roman, Poulter, Barker, McKenna, & Rowe, 2015). Given this, driving experience may instead be leading to improvements in cognitive areas that are necessary to being a safe road user.

Measuring ability to drive

A substantial amount of research has been done in order to establish the best way to assess the driving capability of individuals with cognitive impairments, including off-road screening tools, driving simulators, and on-road assessments (Korner-Bitensky et al., 2005; O'Connor et al., 2008; Szlyk, Myers, Zhang, Wetzel, & Shapiro, 2002). Neuropsychological batteries can measure discrete areas of cognition believed to be associated with safe driving, including planning, attention, and executive function (Szlyk et al., 2002). There are multiple benefits to using pre-screening tests: they have demonstrated predictive ability in relation to motor vehicle accidents (Szlyk et al., 2002); they can be administered in a clinical setting; they are safer than an on-road test particularly if the driver is at risk; pre-screening tools allow clinicians to examine different areas of cognition separately; and they are quicker, more affordable, and less stressful than a driving test. However, in order to be used as a measure of driving ability, these pre-screening tools must demonstrate consistent predictive ability and ecological validity, and this is not always the case (Selander, Lee, Johansson, & Falkmer, 2011). While it is easier to standardise such assessments, it is also more difficult to extrapolate whether a driver is safe on the road via current pre-screening measures alone. There is no consensus on which pre-screening tests should be used as a driving battery; professionals in the area have demonstrated strong agreement that the Useful Field of View and Trail Making Tests should be included in a pre-screening toolkit, but only moderate consensus on multiple others (Korner-Bitensky et al., 2005). The Attentional Network Test has been shown to have predictive ability for on-road driving performance, but only for some of the components (Weaver et al., 2009). Additionally, certain individuals may perform poorly on pre-screening tests but still be safe drivers.

Driving simulators create a realistic driving environment capable of measuring particular aspects of cognitive function without exposing drivers or their assessors to the risk of being on-road (Szlyk et al., 2002). Ideally, these safer alternatives to a behind the wheel assessment can simulate a controlled traffic environment that can present predictable driving hazards to the user while measuring their responses. As with neuropsychological tests, these assessments can be standardized across all participants and enable substantial data collection in terms of exact distances braked, reaction times, and driving behaviors, among others (Lee et al., 2003). Research has found that driving simulator results correlate with performance on some neuropsychological tests (Szlyk et al., 2002; Bedard, Parkkari, Weaver, Riendeau, & Dahlquist, 2010) and on-road driving measures (Lee et al., 2003). As technology advances, driving simulators are becoming more realistic (Parsons, 2015). Despite this, driving simulators have some drawbacks: motion sickness can be induced in simulated driving and participants may be uncomfortable with the simulator equipment (Lee et al., 2003).

The question of ecological validity of both the neuropsychological test batteries and driving simulators continue to leave the on-road driving test as the gold-standard assessment measure (Korner-Bitensky et al., 2005). Driving assessments made from behind the wheel in a real world traffic environment are frequently conducted by professionals specifically trained to make judgments on this type of performance (Stefano & Macdonald, 2010). On-road driving tests enable assessors to measure driving behaviors important to safe road using, including visual scanning and reaction to unpredictable driving events. According to the Michon model, strategic, tactical, and operational skills represent different levels of driving behavior, and the on-road test is the only method which enables an assessor to measure all three simultaneously (Justiss, Mann, Stav, & Velozo, 2006).

This form of driving assessment is the most ecologically valid, and yet multiple variables may impact on its reliability and validity: environmental conditions which cannot be controlled (e.g. weather, traffic conditions), driver factors (e.g. stress, poor driving habits), and differences across assessors (e.g. training, experience of assessments) (Ott, Papandonatos, Davis, & Barco, 2012). On-road measures frequently lack standardisation and are based on subjective global assessor ratings of pass/fail rather than quantifiable test scores (Korner-Bitensky et al., 2005). In addition to being time consuming, expensive, and stressful for those undergoing assessment, they also do not identify which specific areas an individual may demonstrate weaknesses in (e.g. visual attention, executive function). There is strong consensus that an on-road assessment should be offered to individuals who may be at risk while driving, yet there is no standardized assessment measure to do so (Korner-Bitensky et al., 2005). Moreover, the on-road assessments most frequently cited in the driving literature provide scores for behaviors and skills, but do not identify which cognitive areas may be impaired in the test participant without further neuropsychological testing (Justiss et al., 2006; Stefano & Macdonald, 2010; O’Connor et al., 2008).

Current Study

The population of older adults is increasing rapidly in Ireland and throughout the world, as is the number of people licensed to drive (McGill, 2010; Connell et al., 2012). Maintaining the ability to drive is important to achieving a good quality of life into old age (Edwards et al., 2009). There are multiple processes involved in the complex task of driving (Roca et al., 2013b), some of which improve with experience (McKnight & McKnight, 2003) and others which are known to decline with aging (ADEAR, 2008). Keeping people behind the wheel requires that clinicians are able to identify individuals who may be at risk and assess their capacity to remain on the road or return to driving (Korner-Bitensky et al., 2005). Neuropsychological test batteries can identify areas of cognitive decline but lack ecological validity (Selander et al., 2011); on-road tests are considered the gold-standard but they fail to identify particular areas of cognitive decline (Justiss et al., 2006). The goal of the current project was as follows:

1. To explore the differences in cognitive functions across different groups of drivers (novice and experienced drivers, older and younger drivers) given that experience improves driving performance while aging may contribute to cognitive decline. Experienced drivers may see declines in driving ability as a result of aging and so it is important to examine these driving groups separately.
2. To develop a standardised on-road assessment measure capable of highlighting the cognitive domains that may be impaired in the individual being tested.

Chapter 2

Experiment I: The role of cognition in novice and experienced drivers

Abstract

Driving is one of the most dangerous activities that young people can engage in, with novice drivers the most at-risk behind the wheel. The practice of driving improves cognitive abilities necessary for driver safety, and so adults with more experience of driving may demonstrate improved performances on cognitive tests when compared to novices. This experiment compared more and less experienced drivers on self-reported driving ability and measures of cognition thought to be important to driving, including attention, executive function, and memory. The self-reported driving abilities of novice drivers ($M = 5.6$) were significantly lower than those of the experienced drivers ($M = 7.7$). A significant difference was found in response time between experienced ($n = 34$) and novice ($n = 36$) drivers on the Stroop Colour Word test ($p = .03$), a measure of executive function, with novices responding more quickly on each of the three cue conditions. These results indicate that there may be some differences in executive function between more and less experienced drivers, and that the Stroop Colour Word test should be considered as a more sensitive measure of executive function in driver pre-screenings.

Driving is an increasingly common practice in the western world, with many individuals relying on personal transportation to attend work, complete activities of daily living, facilitate social events, and function independently in society (Adler & Rottunda, 2006). Driving is also one of the most dangerous activities that young people can engage in: car collisions with stationary objects was the third most common cause of death among 15-24 year olds in Ireland in 2013 (European Detailed Mortality Database [EDMD], 2016). Collisions with other vehicles and non-collision transport accidents were the 7th and 10th most common causes, respectively (EDMD, 2016). Within the EU, young people comprise 11% of the population and 17% of all road fatalities (European Commission, 2015). Young drivers are associated with more road accidents; different risk factors affect this group, including the number and type of passengers in the vehicle, alcohol and substance use, and length of time from licensure (Williams, 2003).

However, studies exploring the differential effects of age and experience have found that while maturity may be a factor in driving safety, the amount of experience a road user has may be more closely linked to their accident rates than age alone. A study which compared the month-by-month changes in collisions found that the rates of crashes declined most steeply in the first 6 months of driving, and concluded that even a modest amount of driving experience has significant effects on collision rates (Mayhew, Simpson, & Pak, 2003). Sixteen year old drivers have three times as many non-fatal accidents as 18 year olds, and 10 times more than those over 18; yet even when the licensing process is restricted to age 18 and above, the incidence of crashes decreases similarly in the first two years of driving (McKnight & McKnight, 2003).

Research shows that driving experience is directly correlated with incidence rates of motor vehicle accidents, with novice drivers contributing to more road crashes than experienced drivers (Mayhew et al., 2003). Rates of motor crashes decrease across the first 12 months of licensed driving, with a steep decline within the first month alone (McCartt, Shabanova, & Leaf, 2003). Crash rates continue to drop significantly in the first three years of driving while simultaneously the number of driving errors and traffic violations increases (Roman, Poulter, Barker, McKenna, & Rowe, 2015). As such, increasing safety among experienced drivers cannot simply be explained by greater adherence to the rules of the road

As of December 2015, there were nearly 3 million current driving licenses in Ireland; nearly 10% of those were Learner Permits and therefore classified as novice drivers (RSA, 2016). The literature demonstrates that on-road driving experience contributes more significantly to decreasing traffic accidents than maturation alone (McKnight & McKnight, 2003). It is well-established that driving is a complex task which requires the safe coordination of multiple cognitive processes simultaneously (Roca, Crundall, Moreno-Rios, Castro, & Lupianez, 2013b). Scores in measures of visual scanning, attention, and perception differ among novice and experienced drivers; McKnight & McKnight (2003) found that failures to recognize hazardous situations and employ safe driving practices appears to contribute more to motor accident rates than risk-taking driving behaviours such as speeding. However, the researchers also acknowledged the difficulty in identifying such differences given that they are most often self-reported after the fact (e.g. admitting to driver error).

Many neuropsychological tests correlate significantly with driving outcomes (Weaver et al., 2009) and are recommended in multiple studies as an appropriate pre-screening tool for driver safety (Korner-Bitensky et al., 2005; Solander, Lee, Johansson, & Falkmer, 2011; Mazer, Korner-Bitensky, & Sofer et al., 1998). Attention is widely considered to be one of the most important cognitive domains needed for safe driving (Jamson & Merat, 2005). Distraction and lapses in driver attention are considered major contributory factors to motor vehicle accidents (Roca, Lupianez, Lopez-Ramon, & Castro, 2013); as much as 23% of crashes in novice drivers may be attributable to deficiencies in attention alone (Roca et al., 2013). One model that has been shown to be very influential in the driving literature is the attentional network model (Roca et al., 2013b). This model considers three relatively independent attention networks: one that is responsible for sensitivity to incoming stimuli (alerting network), another that chooses where to focus attention (orienting network), and a third that ignores distractors in the environment while resolving conflicting information (executive control network) (Galvao-Carmona et al., 2014). The Attention Network Test (ANT) that attempts to tap into each of these has been shown to predict test scores on simulated driving measures (Weaver et al., 2009). However, other forms of attention not revealed through the ANT, such as sustained attention and vigilance, are also known to play an important role in driving (Drummond et al., 2005; Manly, Robertson, Galloway, & Hawkins, 1999).

Executive function is another key cognitive domain associated with driving (Asimakopulos, 2012). Decision making, planning, mental flexibility, judgment, working memory, and selection of appropriate behaviours in a given circumstance are all attributable to executive function (Asimakopulos, Boychuck, Sondergaard, Poulin, Menard, & Korner-Bitensky, 2012). Disorders commonly associated with deficiencies in this area (e.g. ADHD) have been linked with risky driving behaviours; the literature cites prolonged biological development of the brain into young adulthood as a potential explanation for why young novice drivers may perform more poorly in executive function tasks (Roman et al., 2015; Steinberg, 2008). Greater errors on the Stroop Colour Word test, for example, correlate with high incidences of motor crashes (Asimakopulos, 2012); scores on Trail Making Tests A and B (another test of executive functioning) correlate with driving simulator skills (Szlyk, Myers, Zhang, Wetzel, & Shapiro, 2002) and both are recommended as pre-screening tools because of their predictive value in relation to motor collisions (Korner-Bitensky et al., 2005). Impairments in other cognitive domains that seem to play a role in motor collisions include memory (Lee, Cameron, & Lee, 2003) but the extent to which this is involved is currently under debate. Driving simulators are also frequently used to test performance in a realistic scenario and offer an additional clinical tool to measure at-risk drivers (Bedard, Parkkari, Weaver, Riendau, & Dahlquist, 2010).

Neuropsychological and cognitive tests are often used to assess driver safety prior to conducting an on-road assessment, and there is strong consensus among professional driving assessors that such tools can identify at-risk drivers (Korner-Bitensky et al., 2005). Given the high rates of novice drivers in Ireland and the mortality rates of young people in traffic collisions, it is important to explore whether there may be differences between more and less experienced drivers in scores on cognitive measures known to correlate with driving performance. It is hypothesised that more experienced drivers would perform better on measures of attention, higher order executive functioning and memory compared to novice drivers but no differences between the groups will be found on simple response tasks.

Methods

Participants

Twenty-eight males and 42 females (n = 70) between 18 and 53 years old (M = 23.7, SD = .49) were recruited by convenience sampling, including Maynooth University students, friends, and family members. Participants were required to be at least 18 years of age and have normal or corrected-to-normal vision. Individuals with known attention or other cognitive disorders (e.g. dementia, history of stroke) were excluded. Participants were not required to be a driver but had to indicate whether they had no license, a Learner's Permit, or a Full License.

Materials and Apparatus

Driving History Questionnaire

All participants completed a questionnaire comprising 7 items relating to driving experience, distance driven, type of driving (countryside, city, or both), and a self-report measure for rating their perceived driving ability on a scale of 1 (Poor) to 10 (Excellent) (see Appendix I). Individuals who identified a tendency for motion sickness were given additional information regarding the potential risk of motion sickness while completing a computerised driving task (see below).

Measures of Executive Function

Two measures of executive function were used: the Trail Making Test (A-B) and the Stroop Colour Word task. The Trail Making Test (TMT, Reitan, 1992) is comprised of two parts. In part A, the participant is required to connect a series of numbered circles in numerical order from 1 to 25. In part B, the participant must connect a series of numbered and lettered circles, alternating between numerical and alphabetical order. For example, participants must start on ‘1’ and connect to ‘A’, then find ‘2’, followed by ‘B’ and so forth, with ‘L’ being the final circle. Circles are placed in semi-random fashion on the page and no overlapping lines are created. Both tasks are on paper; the researcher records how long it takes to complete parts A and B. Completion time is the primary outcome measure; errors are accounted for within that time as the researcher will redirect the participant as needed without pausing the clock. These tests measure visual search and tap into higher order cognitive functions including mental flexibility (Bowie & Harvey, 2006). Research has indicated that TMT B-A provides a score which relies less on visuoperceptual and working memory abilities, allowing for a more accurate measure of executive function (Sanchez-Cubillo et al., 2009).

The Stroop Colour Word test (Stroop, 1935) is built on people’s ability to read words faster than they can identify colours, and is used as a measure of cognitive flexibility. Participants are required to identify the text colour of a word as Red, Blue, Green, or Yellow. The words presented on screen may be the names of colours or may be a neutral word; in the case of a colour word, the text itself may be in the same colour as the word (congruent) or a different colour (incongruent) (see Fig. 2.1).

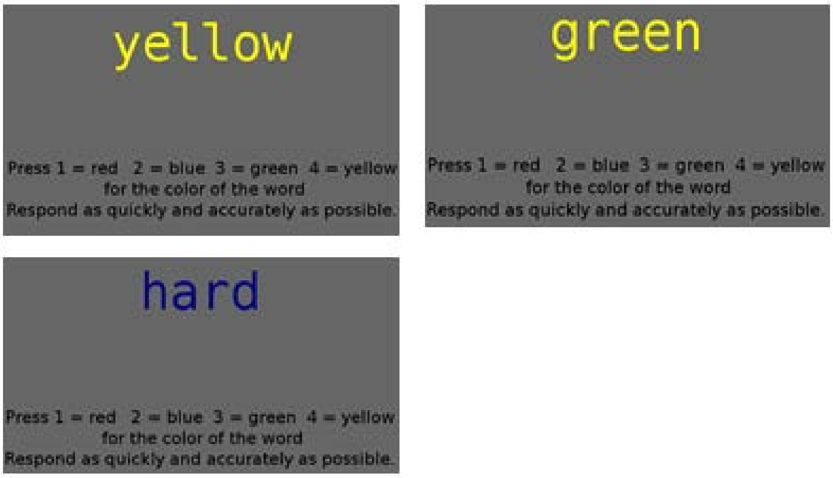

Fig. 2.1 Congruent (top left), incongruent (top right), and neutral (bottom left) cues delivered in the computer version of the Stroop Colour Word test

The Stroop Colour Word task was presented on a computer with the Pebl programme version 0.13, which delivered 3 test blocks and 1 practice block of 48 stimuli (16 of each stimulus type per block). It takes longer to respond to incongruent cues than congruent or neutral cues, and so mean reaction time and total errors are recorded overall and for each type of cue (Cohn, Dustman, & Bradford, 1984). Numbers 1-4 on the keyboard were paired with the colours Red (1), Blue (2), Green (3), and Yellow (4). Participants were given as much time as needed to learn the association between numbers and colours prior to commencing the Stroop test. Participants were instructed to indicate which colour the word was written in and ignore the word itself. The Stroop task took approximately 5 minutes to complete.

Measures of Attention

Three measures of attention were used: the Attentional Network Test (ANT), the Sustained Attention to Response Task (SART) and the Perceptual Vigilance Task (PPVT). Three separate attentional networks are measured via the ANT: alerting, orienting, and executive control (Roca et al., 2013). The ANT was delivered via the Pebl computer programme, version 0.13 (Fig. 2.2a). Participants were required to identify the direction of a central arrow (left or right facing) presented alone or with flankers. If flankers were present, they were facing in the same direction (congruent) or opposite direction (incongruent) to the central arrow (Fig. 2.2b & 2.2c). The arrow cue would appear above or below a cross in the centre of the screen. An additional asterisk stimulus would give location information of the impending arrow cue. If the asterisk appeared above or below the central arrow, it indicated that the arrow would appear in that location (orienting cue); if it the asterisk appeared both above and below the central arrow or in the centre of the screen, no location information was given (alerting cue); no information would be given in the case of an absent asterisk (neutral cue). Configurations of the congruent/incongruent flankers and the alerting asterisk cue were presented pseudo-randomly in equal numbers; RT was measured on four blocks of 144 trials each. The ANT requires attentional control, awareness of incoming stimuli, inhibitory responding, and conflict resolution in order to respond quickly and accurately. The present study aimed to compare differences between the alerting and orienting attentional networks on the ANT, and so target conditions were not included in the analysis (Weaver et al., 2009). Participants were instructed to press the left ‘shift’ key if the central arrow was pointing left, or the right ‘shift’ key if the arrow was pointing right. A practice trial was given. Test trial consisted of four blocks with three breaks and lasted approximately 20 minutes.

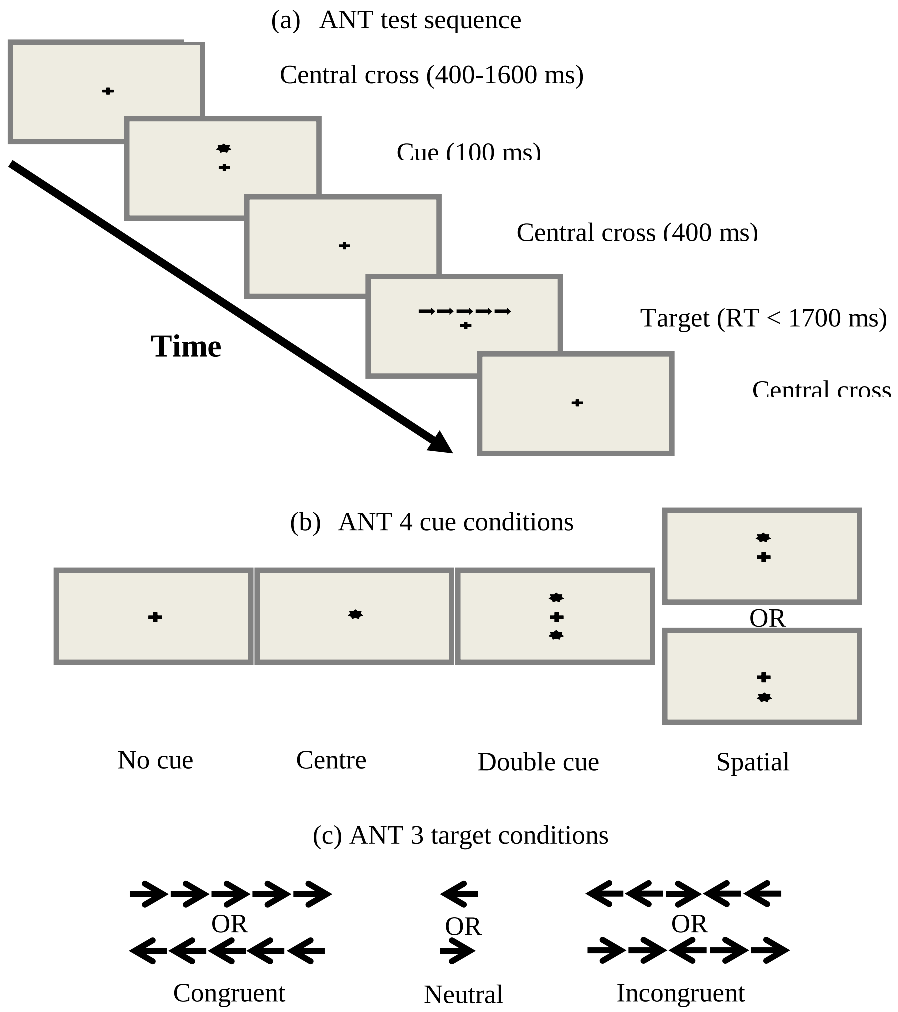

Fig. 2.2 ANT test sequence (a), cue conditions (b), and target conditions (c)

There is a distinction between tasks which are completed automatically and those which require active attentional effort on behalf of the individual. The SART was designed to create a test situation wherein the participant quickly adopts an automatic pattern of responding to go-no-go stimuli (Manly, Robertson, Galloway, & Hawkins, 1999). The numbers 1-9 appear rapidly and randomly on a blank screen. Participants are required to respond via keyboard or mouse-click to every presentation but withhold responding when the digit ‘3’ appears. The nature of the task induces an ‘absentminded’ responding style and thus requires participants to maintain their attention in order to inhibit their responses on the no-go stimuli.

Numbers appear on-screen for 250 ms, followed by a neutral screen for 900ms, before the next stimulus appears for 250ms and so forth. SART was programmed and run on E-Prime version 2.0. Participants were given 18 practice trials followed by 225 test trials; test trials were comprised of 200 'go' stimuli requiring a response and 25 'no-go' stimuli which required no response. Participants were instructed to click the left mouse key as quickly as possible each time a number from 1-9 appeared on-screen, but *not* to respond if the digit '3' appeared. SART ran for approximately 5 minutes. Total responses to the no-go stimuli (errors of commission), failures to respond to 'go' stimuli (omission errors), overall accuracy, and RT were recorded.

The final attention task was the Perceptual Vigilance Task (PPVT). The PPVT examined vigilance/sustained attention by measuring the RT to target stimuli (Drummond, Bischoff-Grethe, Dinges, Ayalon, Mednick, & Meloy, 2005). This was delivered by the Pebl programme version 0.13 via laptop. Participants were presented with a blank screen where a red circle would appear at random intermittent intervals without warning; a response was required as quickly as possible each time the stimulus appeared and RT was recorded. Participants were instructed to press the 'space' bar on the keyboard as quickly as possible each time a red circle appeared on-screen. As the task runs for approximately 20 minutes, it required the individual to remain actively engaged, while any lapses in attention were measured by comparing length of time to respond as the test progressed.

Measure of Response Time

The Simple Reaction Time (SRT) was run through the Pebl programme version 0.13 and completed on a laptop. Participants were required to respond via keyboard each time an ‘X’ appeared on the screen; stimuli were presented at a delay of 250 to 2500 ms from the previous response over four blocks of 50 stimuli. A blank screen was presented to participants who were instructed to press the ‘X’ key each time the symbol ‘X’ appeared on-screen. Time taken to respond to each stimulus was recorded and overall reaction time was calculated. The SRT is designed to be a simple measure of motor response over the course of approximately 5 minutes.

Measures of Memory

The Corsi Block test was used as a measure of spatial working memory span. Pebl version 0.13 was used to deliver the Corsi Block test on a laptop. Nine blocks were presented on-screen and were illuminated in a particular order. Participants were required to recall and repeat the sequence by selecting the boxes in the correct order. Sequences began with 2 blocks and progressed up to 9 blocks. Participants were given two trials per block sequence and must achieve 100% on at least one of the two trials to progress to the next longest block sequence. If 100% was not achieved on at least one of the two trials, the task ended. The total percentage correct for each block sequence was then calculated to determine working memory span.

Computerised Driving Task

Finally, a simple computerised driving task was developed for this study in collaboration with the Computer Science Department at Maynooth University (Dr. Charles Markham). For this task, participants were instructed that they will be in a virtual car and they were required to follow a lead car at a comfortable distance without crashing or falling behind (Fig. 2.3). Participants were instructed to follow the lead car by pressing ‘a’ on the keyboard to accelerate and ‘b’ to brake. If the participant crashed into the lead car, the car speed would reset to zero and testing would continue. The simulator took three minutes to complete. The programme was designed to measure the number of times participants braked, virtual distance at which braking occurred, and virtual following distance.

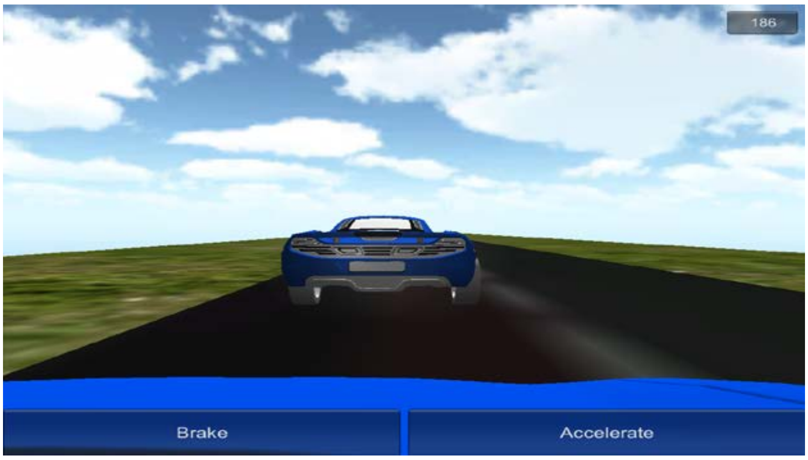

Fig. 2.3 Screenshot of Computerised Driving Task

Procedure

Prior to commencing the study, participants signed a consent form explaining potential risks, anonymity, and right to withdraw from the study at any time (Appendix II). Tasks were completed in a pseudo-random order in one sitting. Data was collected in a designated experimental lab room at Maynooth University. Participants completed the Driving Behaviour Questionnaire (Appendix I) before commencing the cognitive testing battery. All tasks were presented in a random order. Participants were informed that breaks would be offered throughout, but that they were welcome to request a break if needed.

Statistical Analyses

SPSS version 20 was used to analyse the data collected from the test battery. Independent t-tests and mixed between-within ANOVAs were run as appropriate to compare scores between novice and experienced drivers on different performance measures.

Ethical Considerations

This study was approved by the Departmental Ethics Committee at Maynooth University. Informed consent was sought prior to testing and participants were instructed that they could withdraw at any time. There was a possibility of fatigue given the total duration of the testing (up to 1.5 hours); breaks were offered between each test to ensure participant comfort. Participants were informed of the small risk of motion sickness when completing the driving simulator. It was made clear prior to testing that this was not an assessment and individual results could not be obtained. However, participants were recommended to speak with a medical professional if they felt concerned with their ability to complete any of the tests.

Results

Demographic characteristics for all 70 participants can be found in Table 2.1. Participants were divided into driver categories based on their license: no license or Learner's Permit (novice drivers) or a Full License (experienced drivers). N-plate drivers are those who have qualified for their Full License in the last two years and are considered novice drivers by the Road Safety Authority. As drivers are required to wait a minimum of one year from attainment of the Learner's Permit to sit the full exam, and must wear N-plates for 2 years, N-plate drivers have a certain amount of experience which would have rendered them inappropriate in the novice category of the present study. License category was also considered more reliable as a measure of driving experience than self-reported months, as it is difficult to determine how much driving each participant does on a regular basis. Not all participants completed all tests; total participants for each test are included in analyses.

Table 2.1: Demographic characteristics for all study participants. Mean and SEM (in brackets) are given for each relevant characteristic.

	Experienced Drivers (n = 34)	Novice Drivers (n = 36)
	M (SEM)	M (SEM)
Age (years)	27.3* (1.9)	20.3* (.3)
Driving Experience (months)	90.1* (19.3)	15.7* (3.3)
Self-Report Rating (1-10)	7.7* (.2)	5.6* (.5)

* Significant at the $p < .005$ level

The majority of drivers were female in the Experienced (61.8%) and Novice (58.3%) driver groups.. In the Novice driver group, 27.8% were not licensed to drive. Of those with Learner's Permits, 56% of them reported driving less than 5000 km/year. Only 8% of the licensed Novice group drove 8000 km or more per year compared to 55.9% of the Experienced group.

Tests of Attention

Attentional Network Task (ANT)

An independent-samples t-test was conducted to compare the ANT scores for experienced (n = 19) versus novice (n = 22) drivers. There was no significant difference in overall mean reaction time for experienced (M = 575.91, SD = 164.19) and novice (M = 642.22, SD = 266.89; t (39) = -0.94, p = .35, two-tailed) drivers (Fig. 2.4a). The magnitude of the difference in the means (mean difference = -66.31, 95% CI: -209.09 to 76.46) was small (eta squared = .02).

A mixed between-within subjects analysis of variance was conducted to assess the effect of driving experience (experienced versus novice drivers) on participants' reaction times on the ANT in three different cue presentations (spatial, central, and none). There was no significant interaction effect between driving experience and cue type, Wilks' Lambda = .96, F (2, 37) = .67, p = .50, partial eta squared = .04. There was a significant main effect for cue type, Wilks' Lambda = .50, F (2, 37) = 18.78, p < .0005, partial eta squared = .50; all three cue conditions were significantly different from one another. The main effect comparing the two types of drivers was not significant, F (1, 38) = .25, p = .62, partial eta squared = .007, suggesting no difference in reaction times between experienced versus novice drivers (Fig. 2.4b).

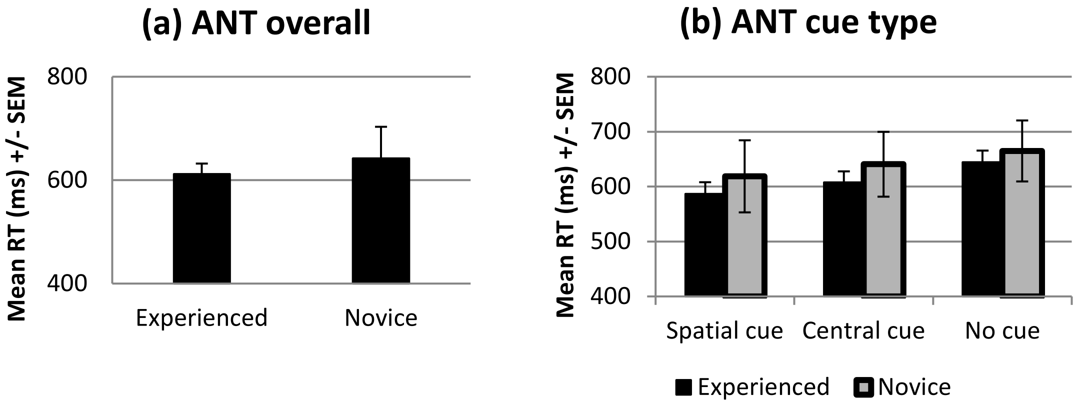

Fig. 2.4 Mean RT of driver groups on the ANT overall (a) and by cue type (b)

Sustained Attention to Response Task (SART)

Mean number of correct responses (target accuracy), errors of omission (failing to respond to a 'go' stimulus), errors of commission (responding to a 'no-go' stimulus), and mean RT to 'go' stimuli and 'no-go' stimuli are presented in Table 2.2. An series of independent t-tests were conducted to compare the SART overall accuracy scores, Target RT, and Errors of Commission RT for experienced (n = 19) versus novice (n = 20) drivers. There was no significant difference in overall accuracy for experienced (M = 209.47, SD = 10.66) and novice (M = 205, SD = 9.86; t (37) = 1.36, p = .18, two-tailed) drivers on SART accuracy; the magnitude of the difference in the means (mean difference = 4.47, 95% CI: -2.19 to 11.13) was small (eta squared = .05). There was no significant difference in RT for Errors of Commission between experienced (M = 212.82, SD = 29.46) and novice drivers (M = 191.11, SD = 14.28; t (37) = .67, p = .50, two-tailed); or for experienced (M = 341.96, SD = 96.44) and novice drivers (M = 295.04, SD = 71.41) on Target RT (t (37) = 1.73, p = .09, two-tailed). All other comparisons were found not to be significant.

Table 2.2: SART mean data for experienced and novice drivers

	Experienced (n = 19)		Novice (n = 20)	
	M	SEM	M	SEM
Target Accuracy	209.47	2.44	205	2.21
Errors of Omission	4.05	1.77	6	6.95
Errors of Commission	11.05	1.45	14.75	1.31
RT Targets (ms)	341.95	22.12	295.04	15.97
RT Errors of Commission (ms)	212.82	29.46	191.11	14.28

Perceptual Vigilance Task (PPVT)

An independent-samples t-test was conducted to compare the PPVT scores for experienced (n = 21) versus novice (n = 19) drivers. There was no significant difference in scores for experienced (M = 401.28, SD = 71.57) and novice (M = 419.45, SD = 85.41; t (38) = -0.73, p = .47, two-tailed) drivers (Fig. 2.5). The magnitude of the difference in the means (mean difference = -18.17, 95% CI: -68.44 to 32.10) was small (eta squared = .01).

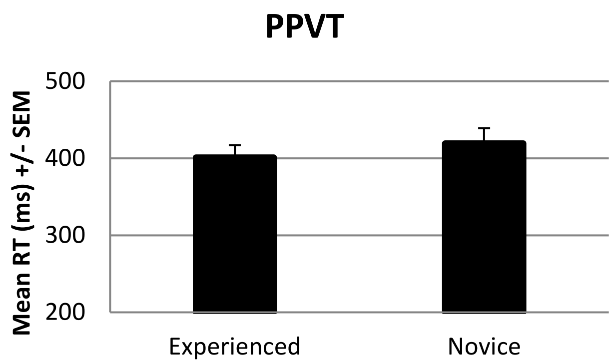

Fig. 2.5 Mean RT on Perceptual Vigilance Task between driver groups

Simple Response Time test (SRT)

An independent-samples t-test was also conducted to compare the SRT scores for experienced versus novice drivers. Again, there was no significant difference in scores for experienced (M = 386.22, SD = 50.98) and novice (M = 397.94, SD = 63.99; t (39) = -0.64, p = .53, two-tailed) drivers. The magnitude of the difference in the means (mean difference = -11.71, 95% CI: -48.68 to 25.25) was small (eta squared = .01).

Tests of Executive Function

Trail Making Tests (TMT)

An independent-samples t-test was conducted to compare the TMT B-A scores for experienced (n = 21) versus novice (n = 19) drivers. There was no significant difference in scores for experienced (M = 20.05, SD = 12.32) and novice (M = 22.49, SD = 17.03; t (38) = -0.52, p = .61, two-tailed) drivers. The magnitude of the difference in the means (mean difference = -2.43, 95% CI: -11.88 to 7.01) was very small (eta squared = .007).

Stroop Colour Word Test

A mixed between-within subjects analysis of variance was conducted to assess the effect of driving experience on participants' reaction times on the Colour Stroop in three different cue presentations (Fig. 2.6a). There was no significant interaction effect between driving experience and cue type, Wilks' Lambda = .92, F (2, 37) = 1.68, p = .20, partial eta squared = .08. There was a significant main effect for cue type, Wilks' Lambda = .27, F (2, 37) = 49.15, p < .0005, partial eta squared = .73. An independent samples t-test found that differences in reaction times between the two groups were significant in the incongruent and neutral cue presentations (Table 2.3).

Table 2.3: Difference in reaction times (ms) between the two driver groups across three cue presentations in the Stroop Colour Word test

	Novice Drivers (n = 19)	Experienced Drivers (n = 21)	Effect size (eta squared)
	M, SD	M, SD	
Congruent	672.96, 98.58	737.72, 114.44	.09
Incongruent	775.88*, 121.83	883.54*, 181.78	.11
Neutral	697.52*, 81.09	776.65*, 132.57	.13

*Significant differences between the two groups at the $p < .05$ level

The main effect comparing the two types of drivers was significant, $F (1, 38) = 4.84$, $p = .03$, partial eta squared = .11, with novice drivers having quicker reaction times compared to experienced drivers. It is important to note that Levene's Test of Equality of Error Variances indicated a violation of the assumption of homogeneity of variance for the incongruent ($F (1, 38) = 4.25$, $p = .05$) and neutral ($F (1, 38) = 4.73$, $p = .04$) cue types. However, as the group sizes are quite similar (n = 21, 19), the analysis of variance can still be interpreted here (Pallant, 2010).

A mixed between-within subjects analysis of variance was conducted to assess the effect of driving experience (experienced = 21, novice = 19) on participants' accuracy on the Colour Stroop in three different cue presentations (congruent, incongruent, neutral; Fig. 2.6b). There was no significant interaction effect between driving experience and cue type, Wilks' Lambda = .96, $F (2, 37) = .75$, $p = .48$, partial eta squared = .04. There was a significant main effect for cue type, Wilks' Lambda = .56, $F (2, 37) = 14.83$, $p < .0005$, partial eta squared = .45; each of the cue conditions was significantly different from one another. The main effect comparing the two types of drivers was not significant (F (1, 38) = 1.87, p = .18, partial eta squared = .05), suggesting no difference in accuracy between experienced versus novice drivers.

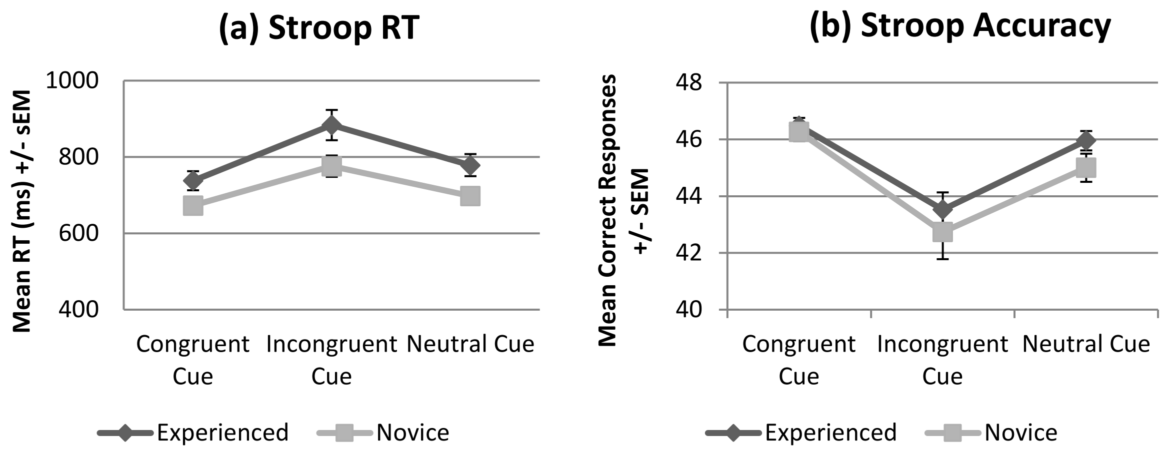

Fig. 2.6 Stroop Colour Word test mean RT (a) and accuracy (b) between drivers across cue types

Corsi Block Test

An independent-samples t-test was conducted to compare the total correct trials between experienced (n = 20) and novice (n = 18) drivers (Fig. 2.7a). There was no significant difference in scores for experienced (M = 8.55, SD = 1.54) and novice (M = 9.0, SD = 1.19; t (36) = -1.0, p = .32, two-tailed) drivers. The magnitude of the difference in the means (mean difference = -.45, 95% CI: -1.36 to .46) was small (eta squared = .03). A mixed between-within subjects analysis of variance was conducted to identify differences between experienced (n = 20) and novice drivers (n = 18) on memory span across the block trials (Fig. 2.7b). Three of the Corsi block spans (2, 8, and 9) violated Levene’s Test of Equality of Variances and Box’s Test of Equality of Covariance Matrices could also not be calculated, so ANOVA results are not reported here.

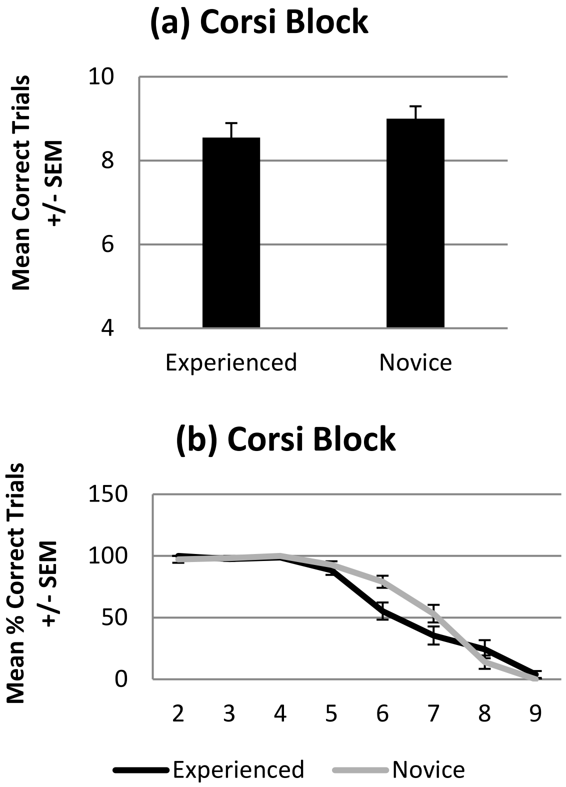

Fig. 2.7 Mean total correct trials (a) and mean % correct trials per block span (b) between experienced and novice drivers

Computerised Driving Task

An independent-samples t-test was conducted to compare the number of times braked during the simulator for experienced versus novice drivers (Fig. 2.8). There was no significant difference in scores for experienced (M = 121.41, SD = 119.32) and novice (M = 133, SD = 108.96; t (70) = -0.43, p = .67, two-tailed) drivers. The magnitude of the difference in the means (mean difference = -11.59, 95% CI: -66.04 to 42.86) was very small (eta squared = .003).

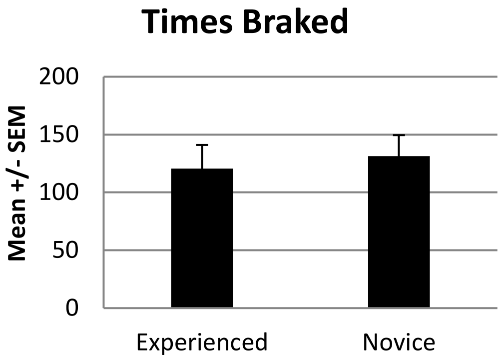

Fig. 2.8 Mean number times braked in computerised driving task between driver groups

An independent-samples t-test was conducted to compare the following distance from the lead car for experienced versus novice drivers (Fig. 2.9a). There was no significant difference in scores for experienced (M = 98.31, SD = 46.13) and novice (M = 82.59, SD = 41.80; t (70) = 1.50, p = .14, two-tailed) drivers. The magnitude of the difference in the means (mean difference = 15.75, 95% CI: -5.23 to 36.75) was small (eta squared = .03).

An independent-samples t-test was conducted to compare the braking distance from the lead car for experienced versus novice drivers (Fig. 2.9b). There was no significant difference in scores for experienced (M = 72.36, SD = 33.13) and novice (M = 67.30, SD = 39.49; t (70) = .58, p = .57, two-tailed) drivers. The magnitude of the difference in the means (mean difference = 5.06, 95% CI: -12.38 to 22.49) was very small (eta squared = .005).

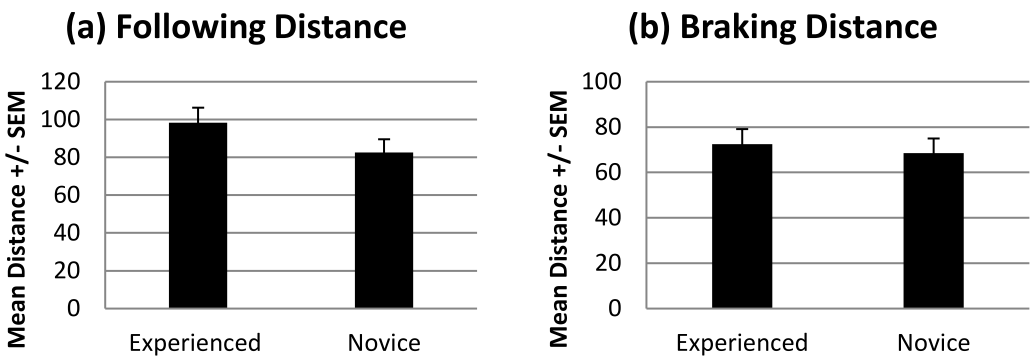

Fig. 2.9 Simulator following distance (a) and braking distance (b) between driver groups

Discussion

Rates of motor vehicle accidents clearly indicate that young novice drivers are at greater risk on the roads than those with more driving experience (Kiss, 2016). Given that errors in the areas of attention, visual searching, and the recognition of hazards have all been linked with collision rates among novice drivers (McKnight & McKnight, 2003), more experienced drivers would be expected to perform better on measures of those relevant cognitive domains. In the current study, none of the measures of attention demonstrated a significant difference in results between experienced and novice drivers. No differences were found for any measure of the ANT. Similarly, tests of vigilance and sustained attention failed to reveal any difference between novice and experienced drivers.

As driver distraction and inattention are significant contributory factors to collision rates among young novice drivers, we had expected to see that experienced drivers would be quicker to respond in both the ANT and SART. Interestingly, studies have shown that experienced drivers take longer to respond to images of difficult traffic situations than comparatively easy ones, but that novice drivers respond as quickly to both types (Owens, Stevenson, Osborn, & Geer, 2009). Given that SART is measuring sustained attention while also requiring that participants withhold responses on the ‘no-go’ stimuli, experienced drivers may be demonstrating more care in responding.

Hazard perception, planning, self-regulation, and mental flexibility are all important elements of driving that can be attributed to executive function (Asimakopulos, 2012). Experienced and novice drivers have been shown to have different eye-scanning patterns during driving, with a greater sensitivity to hazards shown in the experienced driver group (Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003). Measures of executive function, such as Trail Making Tests (TMT) A and B, have been recommended as pre-screening tools for assessing driver risk (Korner-Bitensky et al., 2005). Given that the rates of motor vehicle accidents are higher among new drivers, the novice group would be expected to perform less well than experienced drivers on measures of executive function which correlate strongly with driving outcomes. The TMT can be used to measure decreases in visual processing speed; scores on this test correlate with performance on visual tasks important to driving (Vaucher, Herzig, Cardoso, Herzog, Mangin, & Favrat, 2014). However, again we found no significant difference between the groups on this task.

The Stroop Colour Word task did show a significant effect on measures of reaction time between novice and experienced drivers. These results may suggest that this task is a more sensitive measure of executive function and may be used as a potential way of comparing both types of drivers, particularly as no differences were found on other cognitive measures. Slower reaction times on the Stroop Colour Word task generally indicate poorer executive function (Stroop, 1935); however, experienced drivers have been shown to respond more slowly to images of challenging traffic environments than novice drivers (Owens, 2009). In the present study, the experienced driver group took significantly longer to respond in each of the three cue types than the novice group did. This may be reflective of a more thorough attendance to incoming stimuli, although accuracy scores on this measure did not differ between the two driver groups.

Driving style (e.g. speeding habits, following distance) and driving skill (egg. hazard perception) are independent factors which contribute to motor vehicle accidents (Roman et al., 2015). It was hypothesised that the two driving groups would show different behaviours in a computerised driving task. The tendency to drive with a more ‘risky’ style increases in the first three years of licensure, as do driver errors and traffic violations, while simultaneously the rate of collisions decrease (Roman et al., 2015). Studies have found that younger drivers tend to keep closer following distances (McKnight & McKnight, 2003); leaving a greater space cushion between two cars would be associated with a less risky driving style. No significant differences were found between novice and experienced drivers on the computerised driving task. It may be that driving style is not as strongly correlated with motor vehicle accidents as driving skill. This would pose interesting considerations for driving assessors in the future, particularly as the test requirements for licensure focus on driving techniques rather than behaviours (Korner-Bitensky et al., 2005). It is important to recognize that participants were only able to control acceleration and braking in the driving simulator, and so it is difficult to draw comparisons with performances in a real-world driving scenario. Some studies have cited that memory is not of strong importance in terms of driving behaviour (Vaucher et al., 2014), and so measures of this executive function may be more appropriate in populations known to have significant memory impairments (e.g. dementia). We would concur with this assessment as we did not find any difference between the groups on the Corsi Block test.

In the present study, a portion of the novice group (8%) reported driving more than 8000 km per year; it may be that this group had gained enough driving experience to influence their performance. Studies have shown that even a moderate amount of driving experience (e.g. 6 months) can substantially improve driving outcomes (McCartt, 2003). As Irish Learner’s Permits can be renewed indefinitely, it could be that the current novice drivers were too experienced to be included in that group. It may be helpful in future studies to compare non-drivers with more and less experienced drivers as three independent groups rather than including them in the novice group. Additionally, a non-driver group may elucidate whether any performance differences could be attributed to maturity rather than driving experience alone, particularly as it is difficult to isolate younger versus sufficiently older novice drivers.

In summary, some differences in cognitive abilities between novice and experienced drivers were found, although these results only achieved significance on one measure (Stroop Colour Word test). Further restricting the experimental groups into those with none (zero months), moderate (< 6 months), and substantial (> 6 months) driving experience may yield interesting findings, but there were too few participants in the present study to allow for that more thorough comparison. These preliminary findings indicate that there may well be improvements in cognitive skills associated with driving as a result of more experience; based on our results, future studies might aim to explore differences in the withholding of responses and greater attention paid on the part of more experienced drivers in a larger sample size. Additionally, the Stroop Colour Word test may offer a more sensitive measure of executive function than the Trail Making Test (TMT); given that the TMT is often recommended in pre-screening driver batteries, this warrants further consideration. Identifying differences in cognitive skills would enable more targeted pre-driving training which could contribute to reducing the rates of collisions in at-risk groups.

Chapter 3

Experiment II: The role of cognition in younger and older adults

Abstract

The population of older adults in Ireland is predicted to rise to 28% by 2041; this group is increasingly reliant on driving to maintain their quality of life, but cognitive declines associated with aging may impact on their fitness to remain behind the wheel. In this experiment, younger adults (< 60 years) and older adults (> = 60 years) were compared on measures of cognition relevant to safe driving, including attention, memory, and executive function. Both groups were also compared on an off-road measure known to correlate with driving outcomes (Useful Field of View, UFOV). Older adults took longer to respond on the Attentional Network Test overall ($p = .004$) and in each cue type ($p = .005$). Older adults took longer to respond on the Stroop Colour Word test, a measure of executive function; this was significant at the $p < .005$ level for all three cue configurations. Older adults performed less well on the UFOV subtest 3 ($p < .005$), a measure of selective attention, than younger adults. These results highlight differences in attention and executive function between older and younger adults, and demonstrate that older adults may perform less well on off-road measures of driving ability. None of the results met cut-off points for at-risk drivers; these findings may instead offer a way to identify cognitive decline before it puts older adults at risk on the road. Additionally, the Stroop Colour Word test may be a more sensitive measure of executive function in this population than the Trail Making Test which is often used in pre-screening assessments of at-risk drivers.

Introduction

Ireland's older adult population is rapidly growing: it is estimated that 28% of the population will consist of those over 65 by the year 2041 (McGill, 2010). Maintaining quality of life as the population ages is vital, but this can be made more difficult by shrinking social networks, health impairments, and a loss of independence that can often accompany aging (Centre for Ageing Research and Development in Ireland [CARDI], 2010). Many older adults rely on driving to maintain their mobility, complete their activities of daily live, and retain their self-esteem (O'Connor, Kapust, & Hollis, 2008). Cessation of driving among this population has been linked with increased rates of depression, declining health, and a greater likelihood of having to enter permanent long-term care (Ragland et al., 2005; Freeman et al., 2006). While greater driving experience is associated with decreasing collision risk, older adults are actually on par with young novice drivers for rates of motor vehicle accidents (Richardson & Marottoli, 2003). It has been widely established that driving ability gradually declines with age (Lee et al., 2003), yet older adults are not all the same; multiple factors impact on driving ability (e.g. general ill health, increasing risk of neurodegenerative disorders) (Bowers et al., 2013; Lee et al., 2003). Furthermore, changes occur in the brain (e.g. atrophy, decreasing white matter) as people age (Buckner, 2004) and these inevitably have effects on cognition (O'Connor et al., 2008).

Driving is a complex task which requires the interaction of multiple cognitive skills across a range of domains (Bowers et al., 2013; Roca et al., 2013b). Changes in any one of these may impact on driving, and age is one of a number of factors that is predictive of on-road driving performance (Mazer, Korner-Bitensky, & Sofer, 1998). As people reach old age, changes have been identified in the areas of attention, executive function, and memory (Lee et al., 2003). For example, on measures of three attentional networks (alerting, orienting, and executive control), older adults have demonstrated overall poorer reaction times, greater difficulty with sustained attention, and significant decreases in measures of the alerting network as compared to younger adults (Mahoney, Verghese, Goldin, Lipton, & Holtzer, 2010). Lapses in attention and driver distraction have been linked with higher rates of motor vehicle collisions, while decreased vigilance is considered one of the major causes of road traffic accidents (Roca et al., 2013a; Roca et al., 2013b). Although vision generally declines with age, including the ability to identify appropriate visual information in the environment, rather than being attributable to physical decline, these visual changes have been linked with poorer performance of higher level processes such as visual attention (O'Connor et al., 2008).

Executive function refers to a multitude of complex processes which include decision making, mental flexibility, planning, and conflict resolution (Asimakopulos et al., 2012). This cognitive domain allows for the processing of distracting information received from irrelevant stimuli in the surrounding environment during driving (Weaver et al., 2009). The evaluation of executive function is also important in identifying at-risk drivers during pre-screening, with research indicating that one of the major components being measured during an on-road assessment are the skills associated with higher level executive functioning (Ott et al., 2012). For example, evaluators of the DriveWise programme found that visual analytic abilities and mental flexibility were predictive of performance on road tests (O'Connor et al., 2008). Furthermore, disorders of executive function (e.g. ADHD, Parkinson's disease) have been linked with poorer driving outcomes (Weaver et al., 2009). The ability to self-regulate decreases as executive functioning is diminished (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009) and many older adults avoid risky driving situations by limiting their journeys as they age (Szlyk et al., 2002); it may be that a decreasing ability to self-restrict contributes to rising road accident rates.

Memory is important for the recall of manoeuvres, directions, road sign meanings, and rules of the road. Older adults make more procedural errors in motor vehicle accidents, and are three times more likely to be involved in a crash with ‘right of way’ errors or traffic signal violations than younger drivers (Richardson & Marottoli, 2003). Memory impairment is one of the primary features of Alzheimer’s disease, and general memory decline has been linked with aging (Szlyk, 2002). Although memory assessments have not been strongly linked with driving outcomes in the literature, this domain may show marked decline during aging, as such it is particularly important to explore it further.

Research clearly demonstrates that driving is an important aspect of maintaining the quality of life of older adults, but cognitive abilities diminish as people enter old age (Weaver et al., 2009). These declines may affect driving ability; however, such declines are not uniform across older adults (Lee et al., 2003). While a substantial amount of research in this area has focused on cognitively-impaired older adults, it is also important to identify which domains, if any, may be affected by normal decline in those without impairments (Selander et al., 2011). Are there key driving-related cognitive domains that are diminished in older adults compared to younger adults? Further, can such declines be related to driving performance? One way to explore this is to compare the performance of older adults on various cognitive domains and examine how this may relate to validated tests of off-road performance. One well known measure of off-road performance is the Useful Field of View test (UFOV, Ball, Beard, Roenker, Miller, & Griggs, 1988; Bowers et al., 2013).

The UFOV test is a good off-road measure of driving performance which taps into attentional processes. Older adults who demonstrated limitations in their field of view were six times as likely to have been involved in a motor vehicle collision in the previous five years (Ball, Owsley, Sloane, Roenker, & Bruni, 1993); UFOV subtest 2 results were shown to be the best overall predictor of outcomes on a driving test (Bowers et al., 2013); older drivers whose field of view was reduced by 40% or more were twice as likely to have been in a motor vehicle accident (Owsley et al., 1998). Based on its ability to predict driving outcomes, the UFOV continues to be recommended as a vital pre-screening assessment for at-risk drivers (Korner-Bitensky, Gelinas, Man-Son-Hing, & Marshall, 2005).

The current study aims to compare the performance of younger (< 60) versus older (>= 60) adults on a battery of cognitive tests known to correlate with driving performance to determine whether normal aging results in cognitive impairment which may be relevant to safety on the road. Age cut-offs were chosen based on previous driving literature (Clarke, Ward, Bartle, & Truman, 2010; Mezuk & Rebok, 2008). In addition, comparisons will be made with the UFOV. Identifying normal, predictable declines in cognition can contribute to the development of appropriate pre-screening toolkits, the creation of targeted remediation programmes, and a greater understanding of the risks that older drivers face on the road.

Methods

Participants

Thirty-six participants between 18 and 71 years old were recruited by convenience sampling, including Maynooth University students, friends, and co-workers (see Table 3.1 for demographics). Younger adults were required to be aged between 18 and 59 years while older adults were 60 years and above. Participants were required to have normal or corrected-to-normal vision and a full clean driving license. Health conditions which precluded an individual from driving and/or known cognitive impairments were used as exclusion criteria.

Materials and Apparatus

Driving Behaviour Questionnaire

A 7-item questionnaire was completed which examined driving experience, distance driven annually, driving type (city, countryside, both), and a self-report measure for rating participants' perceived driving ability on a scale of 1 (Poor) to 10 (Excellent) (see Appendix I).

Measures of Attention

The Attentional Network Task (ANT) can be used to measure independent attentional networks. Aging has been associated with decreases in the abilities of the alerting network and slowing of overall reaction time, indicating impairments of sustained attention (Mahoney, Verghese, Goldin, Lipton, & Holtzer, 2010). In the present study, response times were recorded overall and for the no-cue and alerting-cue conditions. As described in the previous chapter participants were required to indicate the direction of a central arrow when presented with or without flankers (congruent or incongruent). The presence of an additional alerting cue occasionally provided location details of the impending target stimulus, but this cue did not always precede the target. Configurations of the congruent/incongruent flankers and the alerting asterisk cue were presented pseudo-randomly in equal numbers; RT was measured on four blocks of 144 trials each. The ANT took approximately 20 minutes to complete.

Measures of Executive Function

The Trail Making Test (TMT) was used as a measure of executive functioning and is a good predictor of errors in driver safety and has been strongly recommended as a pre-screening assessment tool for at-risk drivers (Korner-Bitensky et al., 2005). As described previously, in part A, participants must connect 25 circles in numerical ordered. In part B, participants must connect the circles in alternating numerical and alphabetical order (e.g. 1-A-2-B). Participants are timed on both tasks. Difference in completion time between both parts can be used to measure higher level cognitive abilities (Bowie & Harvey, 2006).

The Stroop Colour Word test was also used as a second measure of executive functioning. The Stroop task is a measure of cognitive flexibility (Golden & Freshwater, 2002) which requires participants to use the keyboard to identify the colour a word is written in (1-Red, 2-Blue, 3-Green, 4-Yellow) while ignoring the word itself. The target words may be the names of colours or neutral words; with colour names, the word itself may be written in the same colour (congruent) or a different colour (incongruent). Mean reaction time was recorded for each of the cue conditions. This test took approximately 5 minutes to complete.

Measures of Memory

Two measures of memory were employed: the Rey Complex Figure and the Rey Auditory Verbal Learning Task. The Rey Complex Figure task assesses visual memory ability. Individuals with dementia have been shown to perform significantly less well on measures of visual memory, immediate recall, and the recognition of complex images; while short term memory has a high correlation with driving score in adults with Alzheimer's (Szlyk et al., 2002). Individuals with Alzheimer's who scored poorly on a complex figure copy task also had more errors in driver safety (Dawson et al., 2009). In the present study, participants were required to copy the figure and reproduce it from memory after a 3-minute delay. Scores were calculated for the delay task.

The Rey Auditory Verbal Learning Task (RAVLT) is a measure of anterograde verbal memory; impairments of this ability are exceedingly common among adults with Alzheimer's disease (Dawson et al., 2009). In the present study, participants were asked to recall a 15-item word list following each reading by the researcher (5 readings in total). A 15-item interference word list was then read to the participant, requiring them to recall as many as possible from the new list. Following this, participants were asked to name as many items from the original 15-word list as possible without having it read to them an additional time (see Appendix III). This task took approximately 10 minutes to complete. Scores reported here are for the final recall of the original word list (time 6).

Simple Response Time test (SRT)

As described in the previous chapter the Simple Response Time test (SRT) required participants to respond via keyboard each time an 'X' appeared on the screen; stimuli were presented at a delay of 250 to 2500 ms from the previous response over four blocks of 50 stimuli. Time taken to respond to each stimulus was recorded and overall RT was calculated. It would be expected that non-significant results on the SRT indicate the same motor response ability between the two driver groups. This task takes approximately 5 minutes to complete.

Useful Field of View (UFOV)

The Useful Field of View test (UFOV) is often used as an off-road performance test (Cosman, Lees, Lee, Rizzo, & Vecera, 2011) and measures visual processing speed on increasingly difficult visual tasks, providing one score (in milliseconds) for each of the three subtests (processing speed, divided attention, selective attention; see Fig. 3.1a. In subtest 1, participants are required to identify whether the image on screen is a car or a truck. In subtest 2, participants must identify the central target (car or truck) and also the location of a second target which appears in one of eight locations around the periphery of the central target. In subtest 3, participants must identify the same information as in subtest 2 but with the addition of distractors in the periphery. In each subtest, central targets are presented within a fixed target box location and appear on screen for varying amounts of time. The UFOV automatically adjusts the length of time the stimulus is presented based on accuracy of the response; a score is obtained when respondents achieve 75% accuracy consistently. Higher scores indicate a tendency to fixate on the central target as a result of narrowing attentional scope. UFOV took approximately 15 minutes to complete.

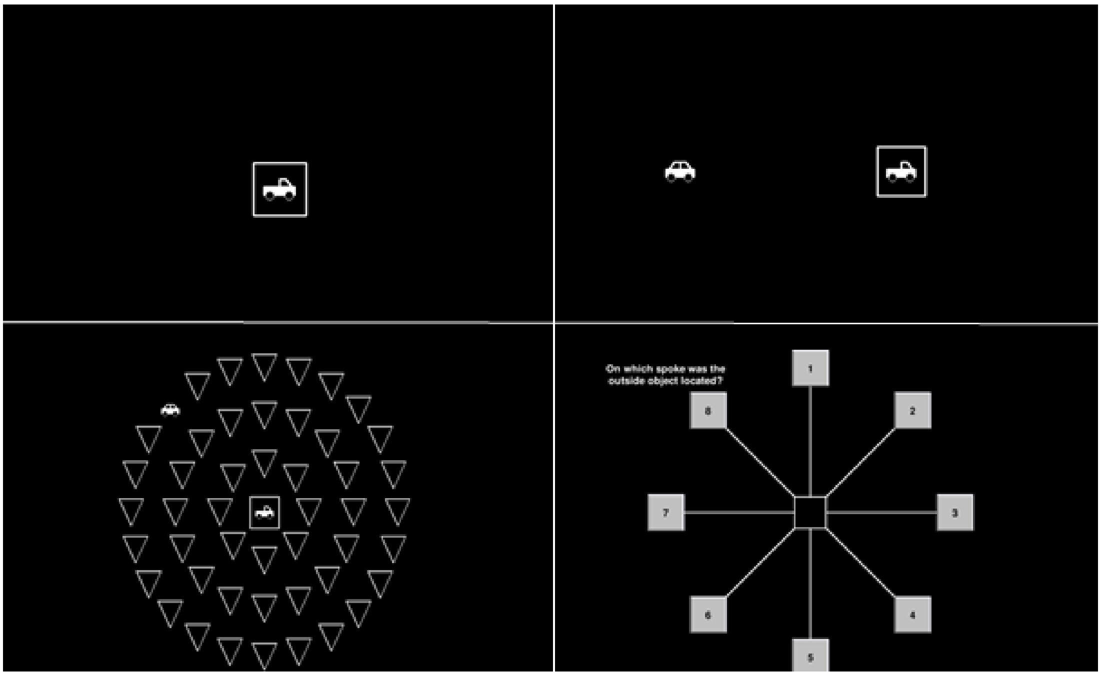

Fig. 3.1a: Subtest 1 (top left), Subtest 2 (top right), Subtest 3 (bottom left), choices for periphery target in Subtests 2 & 3 (bottom right)

Procedure

Prior to commencing the study, participants signed a consent form explaining potential risks, anonymity, and right to withdraw from the study at any time (Appendix II). Tasks were completed in a pseudo-random order in one sitting. All computer tasks were delivered on a laptop at a convenient location for the participant. Participants were informed that breaks would be offered throughout, but that they were welcome to request a break if needed. The total completion time was between 1.5 and 2 hours.

The ANT, Stroop Colour Word Test, and SRT were delivered on a laptop via Pebl version 0.13. Practice trials were provided for each prior to commencing the test. The UFOV version 7 was administered on a laptop. Example and practice trials were given prior to the test for each of the three UFOV subtests. The TMT parts A and B were given following a sample demonstration by the researcher. Completion time was recorded on a stopwatch. For the RAVLT, the researcher read out the word lists according to the description outlined above; a score sheet was used to record correctly recalled words for each participant on each trial (Appendix III). The Rey Complex Figure was the size of one half of an A4 sheet of paper (Appendix IV). Participants were instructed to take as much time as needed to copy the original figure, which was removed upon completion. After a 3-minute delay, participants were asked to replicate the figure as accurately as possible on a new sheet; scores for the delayed recall figure were calculated.

Statistical Analyses

SPSS version 20 was used to analyse the data collected from the test battery. Independent t-tests and mixed between-within ANOVAs were run as appropriate to compare scores between novice and experienced drivers on different performance measures.

Ethical Considerations

This study was approved by the Ethics Committee at Maynooth University. Informed consent was sought prior to testing and participants were instructed that they could withdraw at any time. There was a possibility of fatigue given the total duration of the testing (up to 2 hours); breaks were offered between each test to ensure participant comfort. It was made clear prior to testing that this was not an assessment and individual results could not be obtained. However, participants were recommended to speak with a medical professional if they felt concerned with their ability to complete any of the tests.

Results

Demographic details for the participants who completed the study battery are presented in Table 3.1. The two driver groups were significantly different in terms of age and driving experience, but did not differ on self-reported driving abilities.

Table 3.1: Demographic characteristics for all study participants

	Younger Drivers (n = 26)	Older Drivers (n = 10)	All Participants (n = 36)
	M, SD	M, SD	M, SD
Age (years)	22.81*, 7.69	63.6*, 4.09	34.1, 17.95
Driving Experience (months)	37.73*, 72.65	466.3*, 145.36	156.8, 217.03
Self-Report Rating (1-10)	7.3, 1.09	8.1, .99	7.6, 1.11

*Significant differences between the two groups at the p < .0005 level;

Measures of Attention

An independent-samples t-test was conducted to compare the overall Reaction Time (RT) on the Attentional Network Task (ANT) for younger (n = 23) versus older (n = 9) drivers (Fig. 3.1a). There was a significant difference in scores for younger (M = 634.36, SD = 107.16) versus older (M = 756.45, SD = 69.06; t (30) = -3.15, p = .004, two-tailed) drivers in reaction time on the ANT. The magnitude of the difference in the means (mean difference = -122.09, 95% CI: -201.14 to -43.03) was large (eta squared = .24). A mixed between-within subjects analysis of variance was conducted to assess the effect of age (younger versus older adults) on participants' reaction times on the ANT in two different cue presentations (central/alerting and none). There was no significant interaction effect between age group and cue type, Wilks' Lambda = .99, F (1, 30) = .30, p = .59, partial eta squared = .01. There was a significant main effect for cue type, Wilks' Lambda = .46, F (1,

30) = 35.51, p < .0005, partial eta squared = .54; response times were quicker with the alerting cue than in the no cue configuration (Fig. 3.1b). The main effect comparing the age of drivers across cue type was significant, F (1, 30) = 9.18, p = .005, partial eta squared = .234. These results suggest that age had a large effect on reaction times in the ANT.

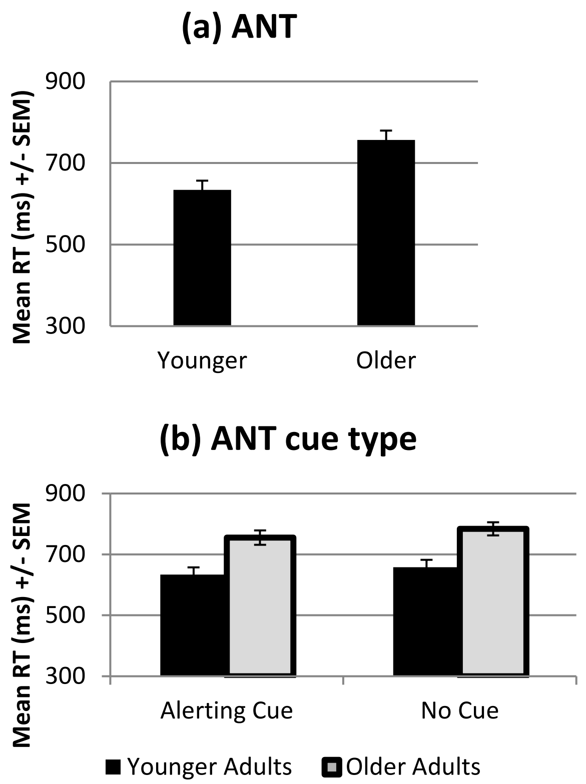

Fig. 3.1 Mean overall RT on the ANT (a) and mean RT by cue type (b)

Measures of Memory

i. Rey Auditory Verbal Learning Task (RAVLT)

An independent-samples t-test was conducted to compare the overall scores on the RAVLT for younger (n = 26) versus older (n = 10) drivers. Younger adults had greater word recall (M = 10.46, SD = 3.02) following the interference list than the older adults (M = 9.30, SD = 2.36) but this was not significant, (t (34) = 1.09, p = .28, two-tailed). The magnitude of the difference in the means (mean difference = 1.16, 95% CI: -1.00 to 3.33) was small (eta squared = .03).

ii. Rey Complex Figure Task

An independent-samples t-test was also done to compare memory recall after a 3 minute delay on the Rey Complex Figure Task between the younger (M = 24.15, SD = 8.34) and older (M = 19.35, SD = 4.33) adults but no significant differences were found (t (18) = 1.62, p = .12, two-tailed). The magnitude of the difference in the means (mean difference = 4.80, 95% CI: -1.44 to 11.04) was moderate (eta squared = .13).

Measures of Executive Function

i. Trail Making Tests A and B

An independent-samples t-test compared overall time taken to complete the TMTs (B-A) between younger (n =, M = 24.15, SD = 8.34) and older adults (n=, M = 51.90, SD = 40.12), but the difference was not significant (t (9.04) = -2.14, p = .06, two-tailed). The magnitude of the difference in the means (mean difference = -29.57, 95% CI: -60.75 to 1.61) was moderate (eta squared = .12).

ii. Stroop Colour Word Test

A mixed between-within subjects analysis of variance was conducted to assess the effect of age on participant's reaction times on the Colour Stroop in three different cue presentations (congruent, incongruent, neutral). There was a significant interaction effect between age and cue type, Wilks' Lambda = .60, F (2, 31) = 10.38, p < .005, partial eta squared = .40. There was a significant main effect for cue type, Wilks' Lambda= .25, F (2, 31) = 45.81, $p < .005$, partial eta squared = .75; each of the cue conditions were significantly different from one another. Due to the significant interaction effect, independent-samples t-tests were also done, with Bonferroni adjustments ($\alpha = .017$) made on each of the three cue presentations (congruent, incongruent, neutral) to limit type I errors. Younger adults responded more quickly on each of the three cue conditions than the older adult group (Fig. 3.2).

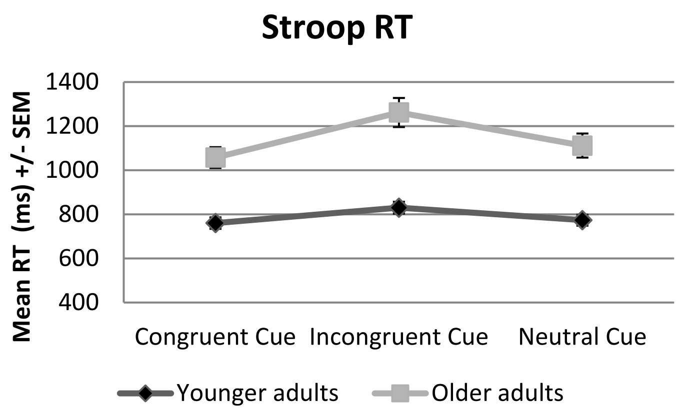

Fig. 3.2 Mean response time differences (ms) across three cue types

Differences in reaction times between the two groups were significant in the congruent, incongruent, and neutral cue presentations (Table 3.2).

Table 3.2: Difference in reaction times (ms) between the two driver groups across three cue presentations in the Stroop Colour Word Test

	Younger Drivers (n = 26)	Older Drivers (n = 8)	Effect size (eta squared)
	M, SD	M, SD	
Congruent	760.28*, 132.62	1057.46*, 133.75	.49
Incongruent	830.28*, 136.91	1261.75*, 186.50	.62
Neutral	773.21*, 125.95	1111.91*, 154.39	.55

* Significant differences between the two groups at the $p < .0005$ level

Simple Response Time test

An independent samples t-test was performed to compare the Simple Response Time of the younger (n = 26) and older (n = 10) adults as a control measure. No significant differences were found between reaction times of the younger (M = 386.53, SD = 56.51) and older (M = 467.41, SD = 153.70) adults (t (9.95) = -1.62, p = .14, two-tailed). The magnitude of the difference in the means (mean difference = -80.87, 95% CI: -192.02 to 30.28) was moderate (eta squared = .07).

UFOV

Variables were assessed for normality using the Kolmogorov Smirnov test.Bonferroni corrections of the α-levels were made to avoid type I errors (α = .017) when doing multiple testing. An independent-samples t-test was done to compare RTs on each of the UFOV subtests. There were no significant differences between younger (n = 23) and older (n = 10) drivers on UFOV subtest 1 (t (31) = 1.27, p = .22, two-tailed) which measured processing speed or on UFOV subtest 2 (t (9.01) = -1.68, p = .13, two-tailed) which examined divided attention. A significant difference was found on UFOV subtest 3 (t (31) = -3.69, p = .001, two-tailed) which indicates that selective attention was affected by driver age (Fig. 3.3) and that this effect size was large (eta squared = .31). All of the participants scored as Low to Very Low risk according to the cut-off classification system devised by the authors of the UFOV (Visual Awareness Research Group, 2009).

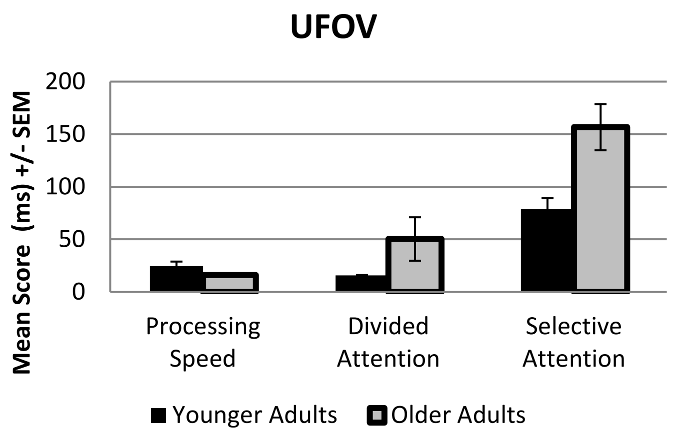

Fig. 3.3 Driver group performance on UFOV subtests 1 (processing speed), 2 (divided attention, and 3 (selective attention)

Discussion

Older adults are at greater risk of motor vehicle accidents than their younger counterparts (European Commission, 2015); numerous studies have linked cognitive abilities with driving outcomes (Bowers et al., 2013; Szlyk et al., 2002; Selander et al., 2011), and these cognitive skills are known to decline with aging (O'Connor et al., 2008). Significant differences were found between younger and older adults on the Attentional Network Task (ANT). Older adults took longer to respond, with 24% of the variance in overall reaction time being attributable to age. Older adults were also significantly slower in responding to the alerting cue, with an equally large effect size of age (23%). Previous studies of the attentional networks have found that older adults show a decrease in performance measures of the alerting network and overall response time (Mahoney et al., 2010); the present findings support this.

In contrast, comparisons on the memory measures (Rey Complex Figure Test and RAVLT) identified no significant differences between the younger and older adult groups. Decreases in anterograde memory are linked with neurodegenerative disorders such as Alzheimer's disease (Alzheimer's disease Education and Referral Centre [ADEAR], 2008) and many patients suffering from this disorder do show driving impairment (Szlyk et al., 2002). However it has also been demonstrated that individuals with severe amnesia have been found capable of driving without much impairment, and so memory may not play a significant role in driving ability (Dawson et al., 2009) as is previously considered. Given that as much as 90% of the information available to a driver is visual, it may be that visual processes such as searching, visual attention, and scanning are more relevant to driving than visual memory (Mazer et al., 2013). Indeed, other types of memory not measured in the present study may be more relevant to driving. Furthermore, given that our sample was healthy and we excluded those with known cognitive impairments, no differences between the groups may have been predicted.

Interestingly, no significant differences were found between older and younger adults on the Trail Making Test (TMT). However, performances on the Stroop Colour Word test were significantly different between older and younger adults on all three cue presentation measures. Age accounted for 49-62% of the variance in reaction times, with older adults responding more slowly. Higher numbers of accuracy errors on the Stroop Colour Word test have been linked with increased rates of driver error (Asimakopulos et al., 2012), but there is limited information on the relationship with reaction time. Previous studies have shown that older adults tend to respond more slowly on this task than younger adults, but that it is not simply a result of slowed speed (Cohn, Dustman, & Bradford, 1984). Indeed, there were no differences between the two groups on the Simple Response Time test. These results indicate that there are declines in executive function in older adults; that this poorer performance was not mirrored in the TMT may indicate that the Stroop Colour Word test is a more sensitive measure of decline in executive function.

We had used the UFOV as an off-road measure of driving performance (see also Korner-Bitensky et al., 2005) and found that younger adults performed better on the UFOV subtest 3 (selective attention) compared to older adults. Interestingly, no differences were noted in terms of processing speed (subtest 1) or divided attention (subtest 2). These findings very much tie into our results on the various cognitive tasks. Our results therefore suggest that visual attention and executive functioning are two important domains that seem to deteriorate with age and these correlate well with driving performance (as measured by the off-road UFOV). Indeed, errors of attention have been linked with higher rates of motor vehicle accidents (McKnight & McKnight, 2003) while declines in visual processing correlate with poorer performances on driving measures (Cosman, Lees, Lee, Rizzo, & Vecera, 2011). The UFOV test was designed on the premise that the primary cause of attention decrements in older adults is a narrowed attentional scope, and that this group have a smaller area over which they can process visual information with a single glance Cosman et al., 2011); scores on this measure have been highly correlated with driving outcomes. Indeed, it is estimated that 90% of the information available to a driver is visual (Mazer et al., 2013).Visual abilities are also known to deteriorate with aging (O'Connor et al., 2008), and the present findings demonstrate significant differences in performances between the two groups on these measures. However, it should be noted that although the UFOV is a good predictor of on-road performances (Korner-Bitensky et al., 2005), simply giving people attentional tasks, such as the ANT, and selected executive tasks, such as the Stroop, may prove to be just as effective at predicting on-road performance (see also Roca et al., 2013b; Asimakopulos et al., 2012).

Older adults have been shown to experience cognitive declines in aging, but the driving literature has tended to focus on those with known impairments (Selander et al., 2011). It is therefore interesting that the present study found significant differences between healthy younger and older adults, particularly where the mean age for the older group was 63.6 years. It is generally accepted that cognitive decline continues as people age, and therefore any impairments would be expected to gradually worsen. Research has clearly indicated that applying restrictions based on age alone is inappropriate and unfair (Korner-Bitensky et al., 2005); while differences were identified between the younger and older adults on the UFOV subtest 3, the older adults did not qualify as an at-risk group based on the cut-off scores provided by the test developers. Further research would be required to identify how these differences in cognitive abilities may impact on real-world driving skills in adults who are not considered at-risk drivers.

It is important to identify that the present study had a relatively small group of older adult participants and that it is difficult to generalize the present findings. It may also be prudent to simplify the Stroop Colour Word test; participants were required to learn the association between colours and the key numbers 1-4, which would have added an additional cognitive burden during the test. However, as this was the same method of administration as in the younger adult group, it is unlikely to yield a different pattern of responding between the two groups. Future studies may build on the current findings by asking participants to identify their driving history (e.g. accidents, traffic violations) in the last number of years, or to include an on-road driving assessment alongside neuropsychological testing of healthy older adults. This would further highlight how the differences in cognition may transfer to driving ability.

In summary, there are clearly differences in cognitive abilities between older and younger adults in the areas of attention (ANT,) and executive function (Stroop Colour Word test) and these matched well with performance on the UFOV. Attentional lapses are one of the major contributing factors in motor vehicle accidents (Harbluk, Noy, Trbovich, & Eizenman, 2007); older adults often self-restrict their driving for safety reasons, but impairments of executive function can diminish the capacity to self-regulate (Adler & Rottunda, 2006). These results may have captured a decline in cognitive abilities which occurs prior to becoming an at-risk driver. As the overarching goal is to keep older adults driving safely for as long as possible, an ability to identify those who are devolving into at-risk drivers may be particularly helpful for clinicians, driving assessors, and the individuals themselves.

Chapter 4

Development of the Maynooth On-Road Driving Assessment

Abstract

Cognitive, neuropsychological, and off-road measures can be used to screen at-risk drivers, but these tests lack the ecological validity of behind the wheel assessments. On-road measures continue to be the 'gold standard' in measuring driver safety, but they may suffer from a lack of standardisation and an objective, quantitative score of the examinee's fitness to drive. Additionally, they fail to identify the cognitive areas which are impaired in those who are found unfit to drive. In this experiment, an on-road driving measure was developed for use in Ireland which could provide a standardised route, a quantitative measure of driving ability, and scores of the cognitive skills necessary for safe driving. The Maynooth On-Road Driving Assessment Maynooth On-Road Driving Assessment was completed by four participants who were each scored by three assessors; strong inter-rater reliability was demonstrated in scores overall (Cronbach's α = .97) and in four of the five cognitive scores (attention, planning, decision making, and memory). However, the inter-item correlation coefficient for the self-regulation measure (IIC = .42) was within the optimum range; driving skills which measure self-regulation on the Maynooth On-Road Driving Assessment Maynooth On-Road Driving Assessment may need to be more detailed so as to reduce the discrepancy in assessor judgment. These results demonstrate that the Maynooth On-Road Driving Assessment may be capable of providing a more ecologically valid cognitive assessment of driver ability in addition to a standardised on-road driving test for at-risk drivers in Ireland.

Introduction

It has been clearly evidenced that driving is a complex task requiring the interplay of skills across multiple cognitive domains (Szlyk, Myers, Zhang, Wetzel, & Shapiro, 2002; Roca et al., 2013b). Driving contributes to independence and well-being, particularly among aging adults who frequently rely on driving as a way to conduct their daily living activities, contribute to familial responsibility, and remain integrated in their communities (Adler & Rottunda, 2006; Edwards, Lunsman, Perkins, Rebok, & Roth, 2009; Ragland, Satariano, & MacLeod, 2005). Experience behind the wheel contributes to the decrease of motor accident rates among drivers, and yet these road risks increase as people enter old age (European Commission, 2015). In addition to decreasing road safety, aging is also accompanied by a gradual cognitive decline (Cosman, Lees, Lee, Rizzoa, & Vecera, 2011). Because driving relies on multiple higher level cognitive skills, decrements in these areas can significantly affect safety behind the wheel (Ott, Papandonatos, Davis, & Barco, 2016). Potentially at-risk drivers are often pre-screened with a battery of neuropsychological and cognitive tests, many of which correlate with driving outcomes (Mazer, Korner-Bitensky, & Sofer, 1998). To date, no pre-screening battery has successfully captured all elements of the driving task sufficiently to eliminate the need for an on-road assessment (Korner-Bitensky et al., 2005).

The on-road driving test enables assessors to identify real-world driving ability and is the most ecologically valid way to determine fitness to drive (Selander, Lee, Johansson, & Falkmer, 2011); this method continues to be the 'gold standard' among clinicians (Justiss et al., 2006). In the case of cognitive impairment, a normal driving test is insufficient to identify fitness to drive; many adults acquire poor driving habits which may earn them demerits on a normal licensing test but which do not make them unsafe behind the wheel (Korner-Bitensky et al., 2005). Additionally, many driving skills which are impaired by cognitive decline (e.g. planning, self-regulation, decision making) cannot be sufficiently captured in a standard on-road test (Justiss et al., 2006). Specific measures which score driver behaviour in addition to vehicle manoeuvring on-road are therefore required when testing at-risk drivers.

On-road measures which test fitness to drive are often based on three skill levels associated with driving: strategic, tactical, and operational (Michon, 1985). Strategic skills are those which generally precede driving; this can include route planning and the making of any necessary adjustments to the original route as required. Tactical skills incorporate those which involve the correct way to manoeuvre in the traffic environment, such as turning corners or observing traffic lights. Operational skills encompass the way that the driver utilizes the vehicle within the traffic environment (Justiss et al., 2006). Assessments which rely on a subjective pass/fail judgment provide less information than those which give a quantitative driving score, and make it difficult for clinicians to identify the areas in which individuals may be declining over time. Additionally, while driving assessors frequently look to cognitive measures to identify whether individuals may be at-risk on the road, on-road assessments do not identify the domains wherein cognition has become impaired.

While driving incorporates many cognitive domains, research in this area has demonstrated a number of higher level skills where impairment directly correlates with driver safety. Lapses of attention and driver distraction are major contributory factors in road traffic accidents (Roca et al., 2013a). The functioning of different independent attentional networks is important to driving, particularly in relation to sustained attention, the interpretation of spatial information, and an ability to ignore distracting stimuli in the environment (Jamson & Merat, 2005). It is estimated that visual information alone comprises as much as 90% of the total information available to a driver; unsurprisingly, measures of visual attention (e.g. Useful Field Of View test) are strongly recommended in any driver pre-screening toolkits (Korner-Bitensky et al., 2005).

Executive function measures (e.g. Trail Making Test) also correlate with driving outcomes (Bowie & Harvey, 2006). Drivers are required to plan safe routes, select appropriate manoeuvres, show good judgment in challenging traffic situations, and make safe decisions throughout (Asimakopulos et al., 2012). Older adults frequently restrict their own driving when they identify impairments in their ability (Connell, Harmon, Janevic, & Kostyniuk, 2012), but this capacity to self-regulate declines as executive function becomes more impaired (see also Chapter 3). An ability to recall correct routes and directions can be affected by memory impairments; even when procedural memory remains intact and driving itself is unaffected (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009), it is still necessary to be able to navigate successfully in order to drive. An ideal measure would be able to assess driver safety while also identifying which of these cognitive domains may be impaired.

A number of on-road assessments designed to test at-risk drivers have been developed and implemented in countries throughout the world, but no such standardised on-road assessment currently exists in Ireland (Korner-Bitensky et al., 2005); given that the population of older adults is predicted to triple in the next 30 years, it is important to develop adequate measures of driver safety (Jamson & Merat, 2005). Pre-screening batteries focus on tests of cognition, and yet on-road driving assessments do not offer results in terms of cognitive domains. Outcomes of on-road measures can include recommendations for remediation (Justiss et al., 2006); if cognitive impairment is responsible for a decrement in driving skill, then being able to target that impairment for therapeutic intervention may offer a way to keep drivers on the road for longer. Given this, the current study aims to develop and test an on-road driving assessment which can be used to evaluate at-risk drivers and provide scores in terms of a global measure of driver safety as well as scores in relevant cognitive domains. Furthermore, the procedure outlined here may be useful for others that may wish to develop other on-road assessments.

Methods

Participants

Four adults aged 23- 27 were recruited by convenience sampling. Participants were required to have a full, clean driving license and normal or corrected-to-normal vision. Exclusion criteria included any cognitive impairment which may have impacted on driving (e.g. history of stroke). Gift vouchers (€25) were offered as an incentive for participation.

Materials and Apparatus

The Maynooth On-Road Driving Assessment Maynooth On-Road Driving Assessmentwas developed (as outlined below) for use in the present study (Appendix VI). A test car (2012 Opel Corsa, 5-door, right-hand drive, manual transmission), supplied by a private driving assessor, was used to drive the route and test each of the participants. Driving and indemnity insurance were provided by the driving instructor A small removable camera (MiVue 518 from Mio) was mounted on the inside of the windshield which recorded each test drive.

Procedure

Developing a driving route

The initial task was to identify a suitable route on which the assessment could be done. By consolidating recommendations from the literature it was possible to identify the main features needed on the assessment route (Korner-Bitensky et al., 2005; Justiss et al., 2006; Stefano & MacDonald, 2010). The driving route was developed based on features recommended by Korner-Bitensky (2005) and Justiss (2006) for a comprehensive on-road assessment.

Naas is a town in Co. Kildare, Ireland approximately 37 km to the west of Dublin (Fig. 4.1). It has a population size of approximately 20,000 people. It is located on the main road connecting Dublin to Cork, Limerick, and Waterford. As a result it has experienced substantial growth in recent years with the influx of the commuter population.

Fig. 4.1 Naas located on Ireland map (left) and road map of Naas (right)

This location was selected for development of the driving assessment for a number of reasons:

(a) Naas is an old town that has a large volume of commuter traffic in the centre as well as on the outer limits. There are a number of residential estates as well as more rural areas not far from the centre and so it provides a challenging mix of rural and urban driving. Additionally, it is located beside the N7 and M7 which provides the added element of motorway driving.

(b) Naas General Hospital serves a catchment area of approximately 180,000 people. It has a 24/7 Accident and Emergency Department, as well as Outpatients and Occupational Therapy departments. The OT department has developed an independent driving programme that caters to stroke, Alzheimer and other patient groups that may wish to continue to drive post-recovery. Furthermore, it also has ample parking.

(c) It is easily accessible via the N7 and M7 from both Dublin and other counties, making it ideally situated for rural and urban participants.

(d) Naas is located near to Maynooth University which is the primary location where the research project was being carried out.

Route selection and details

Google maps were initially used to identify roads and potential driving routes around Naas which centred on Naas General Hospital. Hard copies of the maps were printed and marked out to identify driving journeys that would last the recommended 40 minutes for comprehensive assessment. In order to explore the exact driving route further, Google street view was used (see Fig. 4.2). From this, it was possible to identify potential challenges along the route and develop a draft checklist of driving conditions, including the type of road, intersections, and the driving tasks which would be required along the route (see Table 4.2).

Fig. 4.2 Screenshot of Google street view used to identify driving conditions

Table 4.2 Driving features of the Maynooth On-Road Driving Assessment alongside assessment requirements

	Korner-Bitensky	**Justiss**	**Maynooth route**
General Advantages			
Easily accessible			X
Circuit contains hospital			X
Circuit used for learner drivers			X
Contains mix of urban, rural, suburb and motorway driving			X
Over 40 minutes in length		X	X
Conditions			
4- way intersection	X	X	X
Two way stop	X	X	
Left turn	X		X
Right turn	X	X	X
Traffic lights	X	X	X
Stop sign	X	X	X
Merge that requires speed increase	X		X
Roadway requiring lane position	X	X	X
Lane change	X	X	X
Road with varying speed	X	X	X
Merging at high speed	X		X
Yield to oncoming traffic	X		X
Requires reversing	X		
Behaviours			
Appropriate speed maintenance	X	X	X
Maintaining lane position	X	X	X
	Korner-Bitensky	**Justiss**	**Maynooth route**
Behaviours			
Stopping at red light	X		X
Merging at appropriate speed	X	X	X
Appropriate lane position during turns	X	X	X
Slowing to hazards	X	X	X
Yielding where appropriate	X	X	X
Maintaining appropriate distance	X	X	X
Not spending excessive time at intersections	X		X
Signalling	X	X	X
Scanning traffic environment		X	X
Maintaining driving while completing cognitive task	X		X

Developing the standardised assessment

Once the route was selected and agreed upon, a route assessment was then developed. The initial checklist was modelled on the Washington University Road Test (Hunt, Murphy, Carr, Duchek, Buckles, & Morris, 1997) and incorporated recommendations from the Test Ride for Investigating Practical Fitness to Drive (TRIP, Withaar, Brouwer, & Van Zomeren, 200) and Canadian Association of Occupational Therapists Comprehensive Driving Evaluation (2006) in addition to the studies mentioned previously. The Maynooth On-Road Driving Assessment modified version included turn-by-turn directions as well as space to score driving manoeuvres and behaviours that could be measured at each stage of the route (Appendix V). The initial Maynooth On-Road Driving Assessment driving route was completed twice, each time by a different researcher. A camera was mounted on the windshield and took a video recording of each journey, including GPS points and speed. As one researcher completed the route, the second researcher made notes about the route on the draft checklist. This was done to confirm that the manoeuvers and behaviours on the checklist were appropriate, and also allowed for the checklist to be updated with additional details that were not originally identified via Google maps. The time taken to complete the journey was also measured. The first test drive found that the route took 30 minutes to complete. This was augmented for the second test drive in order to ensure an assessment time of at least 40 minutes; this constituted the final route (Fig. 4.3). Based on the trials completed in Naas, the evaluation checklist was updated with a modified route and additional measures of driving behaviour (Appendix VI).

Fig. 4.3 Map of the Maynooth On-Road Driving Assessment final driving route through Naas

Route testing

The route begins at Naas General Hospital where participants are able to park and meet with the Occupational Therapist/researcher who will be conducting the assessment (Fig. 4.4a). From there, the participant leaves the hospital and completes a short 5 minute circuit that can be used as a familiarisation period prior to beginning the assessment. The participant then continues the drive into the centre of the town and makes their way to the County Council building. This portion of the route will expose the participant to high density traffic that provides a number of driving challenges. Upon arriving at the County Council offices, there is a large parking lot that can be used to assess parking skills.

Participants are then instructed to return to the centre of the town and proceed towards the M7. Directions are provided by the assessor via the Maynooth On-Road

Driving Assessment sheet. Participants are told to join the M7 heading towards Limerick (Fig. 4.4b) and to travel along the motorway until seeing the sign for 'Mondello', at which point they must as for the next instruction (Fig. 4.4c). They are then directed back towards the centre of Naas. Following this, participants are instructed to find a specific housing estate along the route, to locate a particular house without further direction, and to make their way back to the main road from memory. This loop includes a mixture of urban, rural, and motorway driving as well as including a number of roundabouts. It enables an assessor to measure a participant's adherence to traffic rules, reaction to driving challenges, and overall driving competency.

(a)

(b)

(c)

Fig. 4.4 Naas General Hospital (a), directions to M7 Limerick (b), and the 'Mondello' sign on the M7 (c)

Scoring the Maynooth On-Road Driving Assessment

Pre-drive setup and a familiarisation route are examined at the start of the Maynooth On-Road Driving Assessment to determine whether the driver is safe to proceed or if the assessment should be terminated. In addition to a global judgment of Safe/Unsafe at the conclusion of the assessment, quantitative scores are given for each task encountered during the route. Scores of tasks are as follows: Good (4), Acceptable (3), Poor (2), and Very Poor (Justiss et al., 2006). If the task is not encountered, it is left blank and excluded from score calculations. Upon conclusion of the assessment, the investigator calculates a sum total of scores and provides additional scoring on nine tactical skills (e.g. control of steering, control of clutch) which reflect the participant's ability to physically control the car.

Results from the on-road assessment are then transferred to the scoring sheet in order to calculate scores for cognition:

i. Attention/Vigilance: calculated from skills which require sustained attention, switching attention, refocusing on the task of driving, recognition of hazards, and awareness of traffic environment.
ii. Planning: calculated from skills which assess the driver's ability to make adjustments to speed or road position, inform other road users of intended manoeuvres, and alter route as required.
iii. Decision making: calculated from skills which reflect driver's ability to respond to road signs, react to hazards, hesitation during driving, and choice of driving action to take.
iv. Memory: calculated from skills which examine driver's ability to recall instructions provided by the assessor, correct use of car operations, and adherence to the rules of the road.
v. Self-Regulation/Control: calculated from skills associated with maintenance of the car position on the road, regulation of speed, and completion of driving manoeuvres.

In cases where a single driving task can be assigned to more than one of the cognitive skills outlined above, then the score is used in the calculation of each of those skills (e.g. scores on 'Appropriate lane for turn' are assigned to both planning and decision making). A percentage score can then be calculated for overall score and each of the five cognitive skills outlined above.

Testing the Maynooth On-Road Driving Assessment

In order to test the inter-rater reliability of the Maynooth On-Road Driving Assessment, 4 adults were recruited to complete the assessment while being scored by 3 individuals: the two study researchers and a professional driving assessor. During the assessment, the professional assessor sat in the front passenger seat and directed the participants according to the Maynooth On-Road Driving Assessment. Participants were given a score for each task as the assessment progressed. Following testing of the first two participants, it was agreed that an additional directional challenge would capture more by way of cognitive ability. As such, the Maynooth On-Road Driving Assessment was modified to include a navigational challenge prior to the end of the assessment. The final two participants completed this updated route. In determination of scores, only those measures which were assessed on the day were included in the calculations.

Statistical Analyses

SPSS version 20 was used to explore inter-rater reliability among the three assessors in each of the four assessments. Microsoft Excel 2010 was used to calculate scores on the Maynooth On-Road Driving AssessmentMaynooth On-Road Driving Assessment and graph results.

Ethical Considerations

Participants were informed that the test did not constitute a driving assessment and that results would be anonymised. Participants were given time to adjust to the test car and were invited to stop the assessment at any time; they were also informed prior to the test that the driving route would be recorded and informed consent was obtained prior to entering the test car.

Results

Four participants were used to test the Maynooth On-Road Driving Assessment with the same three assessors in each trial. Mean age of the participants was 25 years old (range 23 – 28), and 75% were female (n = 3). Average time for assessment completion was 47 minutes (SD = 4.40) and average journey speed was 54.33 km/h (SD = 2.60). All participants scored very well overall (M = 89%, SD = 1.24), as would be expected in an unimpaired young adult driver cohort. Scores were also high in the attention (M = 92.9%, SD = 1.63), planning (M = 88.8%, SD = .83), decision making (M = 90.1%, SD = .88), memory (M = 85.5%, SD = 2.8), and self-regulation (M =90.2%, SD = .67) cognitive scores. Inter-rater reliability on overall scores and in each of the five cognitive scores was assessed using Cronbach's α coefficient (Table 4.3).

Table 4.3 Inter-rater reliability of scores on the Maynooth On-Road Driving AssessmentMaynooth On-Road Driving Assessment

	Cronbach's α
Overall	.97
Attention	.98
Planning	.92
Decision Making	.95
Memory	.96
Self-Regulation	.55

The inter-rater reliability was strong for all measures except Self-Regulation. However, the mean inter-item correlation value (IIC = .42) on Self-Regulation is within the optimal range (.2 - .4) indicating good internal consistency (Briggs & Cheek, 1986). There were high levels of agreement in scoring between the assessors across the five cognitive measures as well as in overall Maynooth On-Road Driving Assessment score (Fig. 4.5).

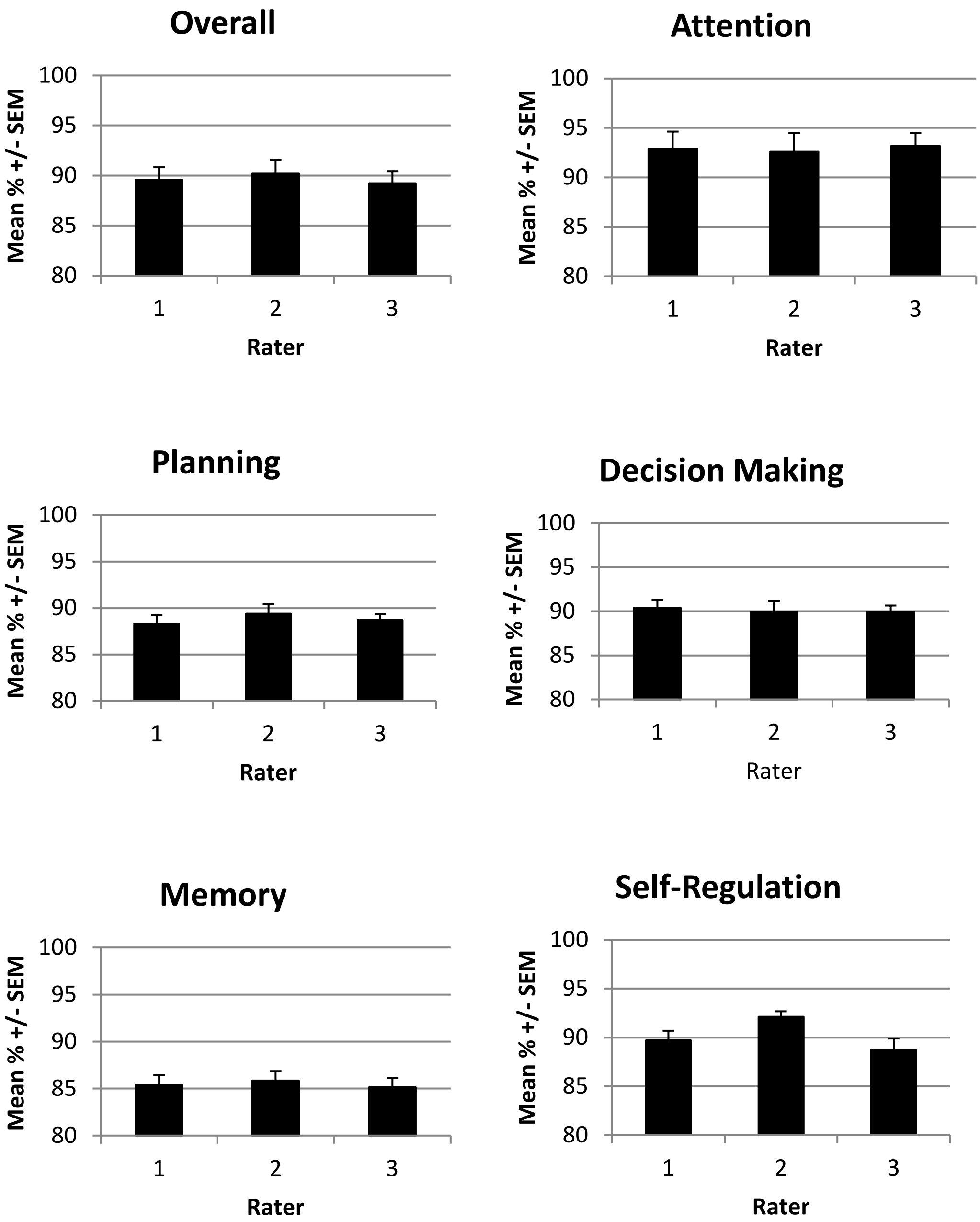

Fig. 4.5 Mean % scores by each assessor (+/- SEM) on the Maynooth On-Road Driving Assessment

Discussion

As Ireland's population of older adults is set to increase substantially over the next 30 years, developing ways of keeping this population behind the wheel for as long as possible is a necessity (Jamson & Merat, 2005). The first step in achieving this is ensuring that there are adequate ways to assess fitness to drive which also identify areas of impairment. Aging is accompanied by gradual declines in cognitive ability, many of which are required for safe driving (Lee, Cameron, & Lee, 2003). Pre-screening of at-risk drivers includes a number of neuropsychological and cognitive tests, but an on-road assessment continues to be the 'gold standard' (Korner-Bitensky et al., 2005). This study aimed to develop an on-road measure which was also capable of providing scores in terms of cognitive abilities as well as general driving abilities.

In the present study, high Cronbach α scores indicated strong inter-rater reliability across the three assessors in overall scores as well as in four of the five cognitive measures (attention, planning, decision making, and memory). However, the inter-item correlation was in the optimal range for scores on self-regulation (Briggs and Cheek, 1986). These preliminary results indicate good agreement between the raters on each of the measures assessed, but more testing needs to be done to identify whether that agreement would remain strong when the participants perform more poorly. Given that the participants in the present study were not cognitively impaired, it was expected that scores would be quite high. Additional testing of the Maynooth On-Road Driving Assessment is required to identify cut-off scores for fitness to drive. It would also be useful to conduct cognitive assessments of individuals prior to completing the on-road driving route; this would enable comparisons between scores obtained on the road and those obtained in the standardized assessments.

When developing an assessment measure, it is important to consider the input of those clinicians most likely to use the tool (Stefano & Macdonald, 2010). While doctors are often required to make judgments on their patient's fitness to drive, surveys have shown that medical professionals feel less qualified to make those kinds of judgments than OT's or driving instructors (O'Connor et al., 2008). For the Maynooth On-Road Driving Assessment, professional input on the selection of the route and driving tasks was sought from occupational therapists and driving assessors. There were a number of challenges associated with the development of a standard route; changeability of traffic conditions, subjectivity of assessor evaluations, and creating a sufficiently challenging test were among them. The scoring sheet for the Maynooth On-Road Driving Assessment was modified to include details relating to weather conditions, lighting, and traffic density during a given assessment, as any of these factors may affect performance.

While it is well-documented that driving is a complex activity relying on the interaction of multiple cognitive skills (Bowers et al., 2013; Roca et al., 2013b), assigning driving behaviours to discrete cognitive abilities presented an additional challenge in developing the Maynooth On-Road Driving Assessment. For example, impaired visual attention may result in a narrowed visual field, thereby limiting the recognition of potential hazards in the traffic environment (O'Connor, Kapust, & Hollis, 2008); as a result, that driver may be less able to make adequate decisions in relation to safe driving. Assessment of a singular driving skill (e.g. reaction to traffic environment) may therefore yield a score which is applicable to both decision making and attention. In the Maynooth On-Road Driving Assessment, one driving task can yield a score for more than one cognitive skill. Ideally, these scores could be weighted in the future with further testing of the Maynooth On-Road Driving Assessment to reflect those driving tasks which are most closely correlated with fitness to drive outcomes. Without having an impaired group to trial the Maynooth On-Road Driving Assessment, it is difficult to say whether this measure can accurately reflect cognitive impairments. Future studies of the Maynooth On-Road Driving Assessment should include a cognitively impaired clinical population in addition to a screening battery which uses tests of attention, memory, and executive function. The Maynooth On-Road Driving Assessment also includes a score for memory, yet studies have shown that even those individuals with severe anterograde memory impairment are capable of driving without much difficulty (Dawson et al., 2009). Indeed, further examinations of this measure could conclude that the scoring of other cognitive skills may be more relevant than the five initially chosen.

The Maynooth On-Road Driving Assessment represents an early step towards development of a standardised on-road driving assessment in Ireland, as well as a way of determining cognitive abilities from behind the wheel. Current on-road driving assessments are not standardised in terms of the route, length of examination, and what is scored; rather, the pass/fail criterion relies solely on assessor judgment. Driving assessors have indicated that while a global assessment of fitness to drive has been the professional standard, the development of specific, quantitative on-road assessments is needed (Stefano & Macdonald, 2010) . Each of the Maynooth On-Road Driving Assessment scores demonstrated strong inter-rater agreement, but it is difficult to say whether that would be the case among a less-fit driver group. The literature has indicated that driving relies on multiple complex cognitive abilities, but on-road measures have not yet evolved to provide scores in different cognitive domains. If researchers can develop an on-road test which is sensitive to declines in separate areas of cognition, it may facilitate the development of therapeutic interventions which can target those declining skills (O'Connor et al., 2008). Indeed, any such cognitive remediation would have benefits which extend beyond the task of driving. As the population of individuals with cognitive decrements is set to rise in the coming decades, it is important to assess driver safety while also developing a greater understanding of *why* a driver may be unsafe behind the wheel. The Maynooth On-Road Driving Assessment presents an opportunity to develop this type of on-road assessment further.

Chapter 5

General Discussion

General Discussion

Novice drivers have high rates of motor vehicle accidents and are at greater risk on the roads than other driver subgroups (McKnight & McKnight, 2003; Roman, Poulter, Barker, McKenna, & Rowe, 2015). Driving experience has been shown to drastically reduce those accident rates, with as little as 6 months of driving experience contributing to significant declines in risk (Mayhew, Simpson, & Pak, 2003). Studies have shown that experienced drivers have different patterns of visual scanning compared to novices, and spend more time attending to hazardous stimuli in images of challenging traffic scenarios (Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003). Collisions among novice drivers have been linked to distraction, with errors of attention contributing to 23% of accidents in an examination of this driver population (McKnight & McKnight, 2003). A study of high school teenagers found that students with low scores on executive function tasks made more errors on a driving simulator (Mantyla, Karlsson, & Marklund, 2009).

As technology advances, people are expected to live longer than ever before; since the 1920s, life expectancy in Ireland has increased by approximately 20 years, with predictions that older adults will comprise 28% of the population by 2041 (McGill, 2010). The number of centenarians in the UK increased by 65% in the last decade (Office for National Statistics, 2016); it is estimated that by the year 2030, as much as 35% of the world's working population will be aged 65 or above (Metz, 2000). Driving is important given the large rural spread of Ireland's population, and among the country's older adults this need is even more pronounced. The ability to travel is required for socialising and to access services and amenities in the community, with an increasing proportion of the elderly relying on their cars to facilitate such travel (Banister & Bowling, 2004). The advent of new technologies has led to the development of vehicles capable of monitoring the traffic environment, including fully autonomous cars; however, there are over 1 billion cars registered worldwide and non-autonomous vehicles are likely to be on the road for the foreseeable future (Coppola & Morisio, 2016). A sense of autonomy, independence, and self-esteem are influenced by the continuing ability to drive (Adler & Rottunda, 2006). Driving cessation has been shown to increase rates of depression among older adults (Raglan, Satariano, & MacLeod, 2005), as well as make it more likely that they will have to enter permanent residential care (Freeman, Gange, Munoz, & West, 2006). That older adults will become one of the largest driver subgroups is unprecedented, and yet this group is on par with young novice drivers for high risks of road traffic accidents (European Commission, 2015). Declining health (e.g. long term illnesses, mobility issues) contributes to decrements in driving ability among this population (Chihuri et al., 2015), but it is not the only causative factor. Aging is accompanied by a gradual decline in cognitive abilities; these include memory impairments (Buckner, 2004), changes in executive functioning (Asimakopulos, Boychuck, Sondergaard, Poulin, Menard, & Korner-Bitensky, 2012), and poorer attention (Roca, Lupianez, Lopez-Ramon, & Castro, 2013a). These cognitive abilities are also imperative to safe driving (Szlyk, Myers, Zhang, Wetzel, & Shapiro, 2002).

While these changes in cognition have been well-established in the research, they are also not uniform across all individuals (Buckner, 2004). Neurodegenerative disorders such as Alzheimer's or Parkinson's disease can develop which may hasten cognitive decline (Szlyk et al., 2002); traumatic brain injuries such as stroke may also contribute to impairment (Brouwer & Withaar, 1997). Memory impairments can decrease driving ability, with one study finding that poorer performance on a word recall task was associated with a 50% higher crash risk in men (Hu, Trumble, Foley, Eberhard, & Wallace, 1998). While cognitive decline is a normal part of aging, it is inconsistent across older adults (Riis et al., 2008). Given that older adults are at greater risk on the road, but that age alone is an insufficient predictor of cognitive ability, clinicians are tasked with the challenge of measuring driver safety of this at-risk group. Current driving assessments of older adults are comprised of cognitive tests, off-road measures, and on-road examinations (Korner-Bitensky, Gelinas, Man-Son-Hing, & Marshall, 2005). Cognitive and neuropsychological tests are capable of predicting driving outcomes (Bowers et al., 2013); the on-road measure continues to be the ‘gold standard’ of driving assessment (Justiss, Mann, Stav, & Velozo, 2006), but these measures can lack standardisation and the ability to provide results in terms of cognitive performance. This project endeavoured to explore the role of cognition in driving by comparing experienced and novice drivers and older and younger drivers, as well as establish a standardised on-road test which could be used to assess the safety of at-risk drivers in Ireland.

In the present study, we found significant differences between novice and experienced drivers on the Stroop Colour Word test. Previous research in this area found that performance on the Stroop test correlates with driving errors (Asimakopulos, 2012); experienced drivers have also been shown to respond more slowly than novice drivers when presented with images of difficult traffic environments (Owens, 2009). In the present study, the experienced driver group responded more slowly than the novice group, which may be indicative of their attending more thoroughly to incoming stimuli. Interestingly, these differences were not mirrored in the results of the Trail Making Test (TMT), despite the fact that the

TMT is strongly recommended as a pre-screening measure of executive function (Korner-Bitensky et al., 2005). It may be that the Stroop test is a more sensitive measure of this cognitive ability; indeed, if this is the case, further research should be done on the Stroop to ensure that it is not overlooked as a vital component of a pre-screening driver toolkit. Our results indicate that there are cognitive differences between novice and experienced drivers, but in order to examine this further, it would be worthwhile to explore more specific categories of novice and experienced drivers. By comparing cognitive abilities between drivers with none (0 months), moderate (< 6 months), and substantial (> 6 months) driving experience across a range of ages, it would be possible to determine how much the practice of driving was contributing to improved performance across different cognitive domains.

As previously outlined, older adult drivers have similar rates of motor vehicle accidents as novices (Richardson & Marottoli, 2003). Despite often having decades of driving experience, which has been shown to increase driver safety (30, Roman et al., 2015), older adults show declines in their abilities behind the wheel (Lee et al., 2003). Decrements in cognition have been attributed to these driving issues, with research demonstrating that older adults are more impaired on cognitive measures than their younger counterparts (O’Connor, Kapust, & Hollis, 2008). It was therefore hypothesised that an assessment of cognitive skills between younger (< 60) and older (>= 60) adults would show significant differences. As predicted, older adults performed less well in tests of attention and executive function, and in an off-road driving measure. Older adults had a longer overall response time on the Attentional Network Task (ANT), which is designed to assess different independent attentional processes; attention is a significant factor in safety on the road, with lapses of attention and driver distraction among the leading causes of road traffic accidents (Roca et al., 2013a).

Older adults took longer to respond on the Stroop test than the younger adult group. Executive function is important to planning, mental flexibility, self-regulation and conflict resolution (Mantyla et al., 2009); each of which are required for the complex task of driving (Asimakopulos, 2012). Surprisingly, again no difference was found in performances on the TMT between the two groups. As with the first experiment, the Stroop Colour Word test appears to be a more sensitive measure of executive function than the TMT and may therefore be more appropriate as a pre-screening cognitive test of at-risk drivers. Younger adults also performed significantly better on the UFOV subtest 3; the UFOV is recommended throughout the literature as an off-road driving measure (Korner-Bitensky et al., 2005). These results indicate that there are differences in cognition between older and younger adults, and that those differences may impact on driving. Age had a large effect size in our results, and therefore may be a more important contributing factor in cognitive ability. Additionally, these differences were found even in a relatively young older adult group (M = 63.6 years). Clinicians and researchers agree that license restriction based upon age alone is unfair and inappropriate (Bowers et al., 2013), and that individuals can be safe drivers well into old age. Indeed, none of our participants met cut-off scores for at-risk drivers. Instead, our results may have captured a snapshot of cognitive ability during the decline associated with normal aging. These findings indicate that it may be possible to test drivers before they become at-risk, not only to further our understanding of the role of cognition in driving, but also to enable us to target those declining areas for remediation and help older adults to remain behind the wheel for as long as possible.

It has been shown that on-road tests are the ideal way to measure driving ability, particularly of at-risk drivers, but that lack of standardisation can lead to difficulties with clinical assessments (Stefano & Macdonald, 2010). A final goal of the present study was to create a standardised on-road measure which could be used in Ireland to test at-risk drivers for fitness to drive while also providing insight into their cognitive capabilities. We were able to successfully integrate the recommendations of multiple on-road measures including the Washington University Road Test (Hunt, Murphy, Carr, Duchek, Buckles, & Morris, 1997), Test Ride for Investigating Practical Fitness to Drive (Withaar, Brouwer, & Van Zomeren, 2000), the Comprehensive Driving Evaluation (Canadian Association of Occupational Therapists, 2006), and the Behind the Wheel assessment developed by Justiss and colleagues (2006). We also sought the input of professional driving assessors and occupational therapists in the development of the Maynooth On-Road Driving Assessment. According to Cronbach α scores, the inter-rater reliability across all measures of the Maynooth On-Road Driving Assessment was high except in self-regulation scores. Tasks attributed to self-regulation on the Maynooth On-Road Driving Assessment may need to be more detailed so as to improve agreement among assessors as to how well the manoeuvre was completed by the examinee. However, as the inter-item correlation value for self-regulation was within the optimal range, it may be that the small sample size of test drives contributed to a low Cronbach's α more so than a significant difference in assessor ratings.

Our results demonstrate that it is possible to develop an on-road measure which can provide scores of different cognitive abilities in addition to an overall driver safety score. Future studies exploring the Maynooth On-Road Driving Assessment, or hoping to develop a new on-road driving test with cognitive scoring capabilities, should examine performance differences between impaired and unimpaired driver groups. As we have shown in our second experiment, older adults and younger adults may provide sufficient differences in cognition to validate any such measures. Additionally, it would be worthwhile to use a pre-screening battery of neuropsychological and cognitive tests to determine how well those results correlate with cognitive scores provided by the on-road assessments. As a behind the wheel assessment is the most ecologically valid measure of driver safety (Justiss et al., 2006), identifying the most important driving-related cognitive abilities would be most valid if assessed during the actual task of driving.

Some limitations of the thesis include the relatively small sample size of older adults used in the second experiment (n = 10). However, even with a limited, unimpaired older adult group, significant differences in cognitive abilities were found. It would also have been beneficial to be able to test the Maynooth On-Road Driving Assessment in a clinical population of cognitively impaired adults, as this would enable us to determine how sensitive the measure is to specific decrements of cognition. That we could only test it among four drivers means that the results should be considered preliminary. However, as the inter-rater reliability was strong both overall and in the cognitive measures, the Maynooth On-Road Driving Assessment does seem to offer a standardised method of assessing at-risk drivers on the road in Ireland. It should also be noted that while driving experience contributes to differences in cognition, other variables may account for differences in these areas. For example, a study of high school students found that errors of executive function correlated with driving simulator errors, and that this effect was more pronounced in those teens who had limited experience of video games (Mantyla et al., 2009). The researchers concluded that skills learned in video games contributed to improved cognitive abilities associated with better performance on a driving task. Given this, it would be prudent to compare non-drivers, new drivers, and experienced drivers across multiple age groups to identify cognitive differences which can be attributable to driving experience alone.

The thesis identified significant differences on a measure of executive function and self-reported driver ratings between novice and experienced drivers. Significant differences were found between older and younger adults in attention, executive function, and on an off-road driving measure. We identified that the Stroop Colour Word test may be a more sensitive measure of executive function than the Trail Making Test; we therefore suggest that the Stroop test should be utilized in a cognitive pre-screening toolkit of at-risk drivers. Finally, we developed and tested the Maynooth On-Road Driving Assessment which can be implemented in Ireland. Preliminary results indicate that this measure is capable of providing an overall fitness to drive score as well as an assessment of cognitive skills necessary for driver safety. These findings represent steps towards integrating the ecological validity of on-road testing with cognitive results that can be used to develop targeted cognitive remediation interventions for drivers. Given that the population of older adults is set to increase dramatically in the next few decades, it is important that we augment our understanding of how to keep this driver group on the road for as long as possible. Not only will this contribute to a greater quality of life of the older adult in Irish society, but it will also help make the road a safer place for all users.

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Appendix I: Driving Behaviour Questionnaire

Questionnaire on Driving Behaviour

Name: Age:

Instructions: Please place a tick (✓) in the box next to the response of your choice or write your response in the space provided where appropriate.

1. Please indicate whether you hold a Learner Driver's Permit or a Full Driving Licence:
   a. Full Licence ☐
   b. Learner's Permit ☐

For Question 2, please indicate how many years you have held your current licence for. If you have held your Full Driver's Licence for less than 2 years, please provide the number of months you have held the licence.

2. For how long have you held the particular licence? _____ years _____ months

3. How many kms per year do you think you drive?

<5,000 Km 5,000-8,000 Km 8,000-12,000 Km >12,000 km

4. Please indicate where you typically do most of your driving:

   a. City/Urban ☐

   b. Countryside ☐

   c. Both city and countryside ☐

5. Do you have any medical conditions that prevent you from driving? (Visual impairment, epilepsy, a heart condition, etc.)

   a. Yes ☐

   b. No ☐

6. Have you ever experienced car sickness or motion sickness?

   a. Yes ☐

   b. No ☐

7. Please indicate, on a scale of 1 to 10, 1 being poor and 10 being excellent, how you would rate your own driving ability. Please circle the appropriate response.

1 2 3 4 5 6 7 8 9 10

Poor **Excellent**

Appendix II: Consent Form

Maynooth University
National University of Ireland Maynooth

PARTICIPANT CONSENT FORM

Study title: Cognition and driving behaviour.

This study and this consent form have been explained to me. I understand what will happen if I agree to be part of this study.

I have read this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand that a signed copy will be sent to Maynooth University.

PARTICIPANT'S NAME:

____

PARTICIPANT'S SIGNATURE:

____

Date: ______________

Date on which the participant was first furnished with this form: ______________

Statement of investigator's responsibility: *I have explained the nature, purpose, procedures, benefits, risks of, or alternatives to, this research study. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.*

Investigator's signature: ______________________________________

Date: ______________

It must be recognized that, in some circumstances, confidentiality of research data and records may be overridden by courts in the event of litigation or in the course of investigation by lawful authority. In such circumstances the University will take all reasonable steps within law to ensure that confidentiality is maintained to the greatest possible extent.

Appendix III RAVLT Word List

RAVLT Sample Scoring Sheet

Name & Age: ____________________

Date: ____________________

Examiner: ____________________

(Note: do not re-read List A for Recall A6)

Do Not Re-read List A → A6

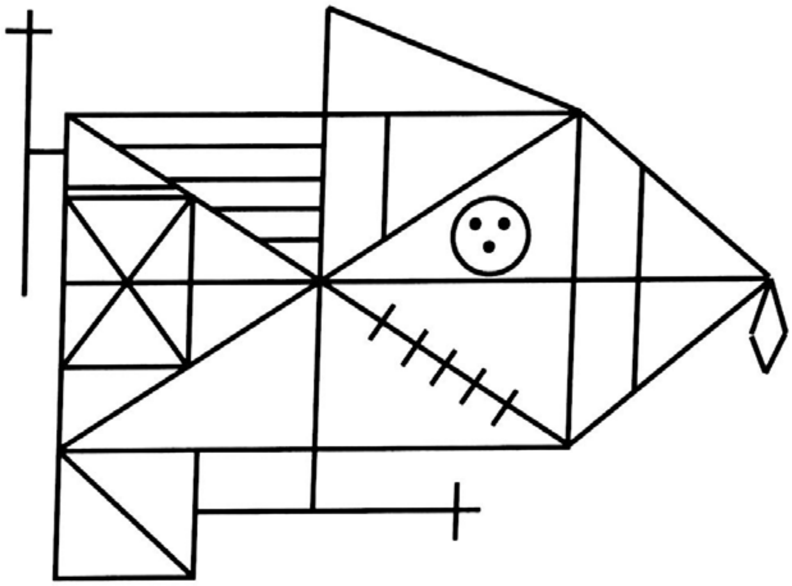
List A	A1	A2	A3	A4	A5	List B	B	A6	List A
Drum						Desk			Drum
Curtain						Ranger			Curtain
River						Fish			River
Bell						Bird			Bell
Coffee						Shoe			Coffee
School						Stove			School
Parent						Mountain			Parent
Moon						Glasses			Moon
Garden						Towel			Garden
Hat						Cloud			Hat
Farmer						Boat			Farmer
Nose						Lamb			Nose
Turkey						Gun			Turkey
Colour						Pencil			Colour
House						Church			House
# Correct									

Total A1 to A5 = _______

Trial A6 - A5 = _______

Appendix IV Rey Complex Figure

Please draw the figure below on the blank half-sheet that was given to you:



Appendix V First draft of the on-road assessment measure

IN-CAR, OPEN ROAD DRIVE EVALUATION

OPEN ROAD TEST

A score of 0 indicates normal (unimpaired) performance. If behaviour or skills are impaired, then points score = 1 indicates mild impairment and score = 2 indicates moderate/severe impairment and 3 = not applicable or opportunity did not occur.

Directions: Signal at all turns and lane changes; turn head at all lane changes; beginning at Osprey Hotel.

A. At the roundabout, take the 2nd exit onto John Devoy Road.			
1. Signals (0 = uncued, timely; 1 = needs verbal cueing; 2 = does not signal with verbal cueing).	0	1	2
2. Checks traffic	0	1	2
3. Does not hesitate without reason	0	1	2
4. Accelerates to appropriate speed	0	1	2
5. Car in appropriate lane for turn	0	1	2
B. At the junction, turn right.			
1. Signals (0 = timely signal, 1 = late signal, 2 = does not signal at all)	0	1	2
2. Speed control (0 = accurate; 1 = 5mph above or below speed Limit; 2 = more than 5 mph)	0	1	2
3. Checks traffic before turning (1 = looks in direction; 2 = does not look)	0	1	2
4. Does not hesitate without reason before proceeding	0	1	2
5. Traffic light observance	0	1	2
6. Car in appropriate lane for right turn	0	1	2
7. Stays in lane	0	1	2

C. At the T-junction, take the left onto Main Street.

1. Traffic light observance	0	1	2
2. Appropriate speed for turn	0	1	2
3. Stays in lane	0	1	2

D. Continue straight at the junction with R407.

1. Does not hesitate without reason	0	1	2
2. Yields to oncoming traffic	0	1	2
3. Selects appropriate lane	0	1	2

[E. F. and G. refer to drive from R407 to the motorway]

E. Lane Keeping	0	1	2
F. Appropriate speed (between 5 miles per hour or more below speed limit or 5 miles per hour above speed limit)	0	1	2

G. Awareness of Traffic Environment

1. Checks mirrors	0	1	2
2. Looks ahead at traffic	0	1	2
3. Reacts to flow of traffic	0	1	2
4. Awareness of how driving is affecting others	0	1	2
5. Attends to task of driving	0	1	2

H. Continue onto the N7/M7.

1. Problem solves for appropriate lane selection	0	1	2
2. Car in appropriate lane for turn	0	1	2
3. Appropriate speed for merging	0	1	2
4. Does not hesitate without reason	0	1	2

5. Mirror use when merging (0 = looks over right shoulder; 1 = only uses right Mirror; 2 = does not check traffic)	0	1	2
I. Take Exit 10 to leave the motorway.			
1. Appropriate planning for exit (0 = prepared for exit; 1 = fails to signal and/or Choose appropriate lane; 2 = misses exit)	0	1	2
2. Plans to stop by slowing down	0	1	2
J. Turn left onto Newbridge Road.			
1. Sign observance for complete stop	0	1	2
2. Yields right of way	0	1	2
3. Does not hesitate without reason	0	1	2
4. Signals	0	1	2
K. At the roundabout, take the 1st exit onto R445.			
1. Signals	0	1	2
2. Yields right of way	0	1	2
L. Continue straight on R445.			
1. Awareness of traffic environment	0	1	2
2. Speed control	0	1	2
3. Appropriate reaction to merging car	0	1	2

Proceed to turn right onto John Devoy Road, continue straight, and park.

M. Has No Lapses of Concentration	0	1	2
N. Follows Directions	0	1	2
O. Overall Judgement	0	1	2

TOTAL SCORE ______________

P. Requirement for Driving Assistance
(i.e. instructor uses dual brake or steering wheel) **Yes _____** **No _____**

Q. Non-Standard Situation – Describe (i.e. hazard detection): -

____
____
____
____

R. Investigator's Global Judgement of Driving Safety:
(determine prior to calculation of total score above)

Occupational Therapist:	**(1). Safe _____**	**(2). Unsafe _____**
Driving Instructor:	**(1). Safe _____**	**(2). Unsafe _____**

Appendix VI Final Maynooth On-Road Driving Assessment (Maynooth On-Road Driving Assessment)

MAYNOOTH ON-ROAD DRIVING ASSESSMENT (Maynooth On-Road Driving Assessment)

Name (if appropriate) ___________________________________

Date ______________________**Time:**__Start ______________Finish___________

Lighting ____

Weather ____

Traffic conditions: Light Medium Busy

Driving Experience

Years _____________ **Months**_________

Age _________

Gender ____

Each task should be scored from 1 – 4. Leave blank if not assessed or did not encounter during route.

Scoring:

4	**3**	**2**	**1**
Good	Acceptable	Poor	Very Poor

Pre Drive Setup

1. Driving position and correct mirror alignment	4	3	2	1
2. Ensure doors are closed and seat belt on	4	3	2	1

Familiarisation Route:

Directions to driver: Signal at all turns and lane changes; turn head at all lane changes.

Turn left from Naas General Hospital; Right on R411; Left on R448; 1st exit at roundabout; 1st exit at roundabout.

Upon completion, examiner should determine whether driver is safe to proceed or if assessment should be terminated.

Familiarisation of route: Safe ____________ Unsafe _________

PART A TACTICAL SKILLS

Proceed to direct driver as to route. Select most appropriate score from 1 – 4 (as outlined above).

Continue straight on R411.

1. Maintains distance appropriately	4	3	2	1
2. Appropriate lane position	4	3	2	1
3. Speed maintenance	4	3	2	1
4. Awareness of environment	4	3	2	1

At the junction, turn right onto R448.

5. Use of turn signals	4	3	2	1
6. Appropriate lane for turn	4	3	2	1
7. Speed maintenance	4	3	2	1
8. Checks traffic before turning	4	3	2	1
9. Hesitates appropriately before proceeding	4	3	2	1
10. Remains in lane	4	3	2	1

At the traffic lights, turn left onto *New Row*.

Instruct driver to remember this location

11. Use of turn signals	4	3	2	1
12. Remains in lane	4	3	2	1
13. Speed maintenance	4	3	2	1
14. Awareness of environment	4	3	2	1

Pass the Petrol Station and turn left onto John Devoy Road.

15. Use of turn signals	4	3	2	1
16. Remains in lane	4	3	2	1
17. Speed maintenance	4	3	2	1
18. Awareness of environment	4	3	2	1
19. Ability to understand instruction (turn left without reminder) Y/N	4 -Y			1-N

At the roundabout, take the 2nd exit onto John Devoy Road.

20. Yields right of way	4	3	2	1
21. Completes movement when appropriate	4	3	2	1

Turn right into the County Council parking lot.

Instruct driver to select a parking space suitable to them and park the car

22. Follows directions	4	3	2	1
23. Selection of appropriate space	4	3	2	1
24. Completion of manoeuver	4	3	2	1

Exit the County Council parking lot and return to *New Row*.

Only give following instruction if required

At the roundabout, take the 1st exit onto John Devoy Road.

25. Use of signals	4	3	2	1
26. Checks traffic	4	3	2	1
27. Yields right of way	4	3	2	1
28. Completes movement when appropriate	4	3	2	1

Only give following instruction if required

At the junction, turn right.

29. Use of signals	4	3	2	1
30. Appropriate lane	4	3	2	1
31. Speed maintenance	4	3	2	1
32. Traffic light observance	4	3	2	1
33. Checks traffic before turning	4	3	2	1
34. Hesitates with appropriate reason only	4	3	2	1
35. Stays in lane	4	3	2	1

36. Reaches New Row without instruction (Y/N)	4-Y			1-N

When at NEW ROW ask if can recall the name of this street

37. Ability to recall name (Yes, No, slightly)	4-Y			1-N

At the T-junction, take the left onto Main Street.

38. Use of signals	4	3	2	1
39. Hesitates with appropriate reason only	4	3	2	1

40. Remains in lane	4	3	2	1
41. Speed maintenance	4	3	2	1
42. Awareness of environment	4	3	2	1

Park Car anywhere along Main Street

43. Planning, preparation and execution	4	3	2	1

Select correct lane and continue straight on the R445.

44. Appropriate distance from car ahead	4	3	2	1
45. Lane position	4	3	2	1
46. Maintenance of speed	4	3	2	1
47. Checks mirrors	4	3	2	1
48. Reacts to flow of traffic	4	3	2	1
49. Reacts to changing environment	4	3	2	1
50. Attends to task of driving	4	3	2	1
51. Reacts to pedestrian lights	4	3	2	1
52. Changes speed as per signage	4	3	2	1

Continue onto the N7/M7 towards Limerick.

53. Lane selection	4	3	2	1
54. Use of turn signals	4	3	2	1
55. Appropriate speed	4	3	2	1
56. Checks traffic	4	3	2	1
57. Hesitates with reason only	4	3	2	1
58. Use of mirrors	4	3	2	1
59. Completes movement when appropriate	4	3	2	1

Remain on Motorway.

Provide driver with following instruction: "Continue driving as normal, keeping to the speed limit. When you see the sign for 'Mondello', ask me for the next direction"

60. Overtaking	4	3	2	1
61. Speed maintenance	4	3	2	1
62. Distance from car ahead	4	3	2	1
63. Identifies 'Mondello' sign (Y/N)	4 - Y			1-N
64. Asks for next direction (Y/N)	4 - Y			1- N

Take Exit 10 to leave the motorway.

65. Plans for exit (signal at ///)	4	3	2	1

66. Speed maintenance	4	3	2	1

Turn left at the top of the slip road.

67. Use of turn signals	4	3	2	1
68. Complete stop at sign	4	3	2	1
69. Turns when appropriate	4	3	2	1
70. Hesitates with reason only	4	3	2	1

Take the 1st exit at the first roundabout and take the 2nd exit on the second roundabout

71. Use of turn signals (first roundabout)	4	3	2	1
72. Yields right of way	4	3	2	1
73. Turns when appropriate	4	3	2	1

74. Use of turn signals (first roundabout)	4	3	2	1
75. Yields right of way	4	3	2	1
76. Turns when appropriate	4	3	2	1

77. Ability to follow instruction without reminding Y/N	4 -Y			1 - N

Continue straight on R445 until reach a T-JUNCTION.

Ask driver what the posted speed limit is and to inform you if it changes*

78. Distance from car ahead	4	3	2	1
79. Lane position	4	3	2	1
80. Maintenance of speed	4	3	2	1
81. Awareness of environment* 50km to 60km	4	3	2	1
82. Reaction to pedestrian lights	4	3	2	1
83. Understanding of T-junction	4	3	2	1

At the traffic lights, turn right onto Main Street.

84. Use of turn signals	4	3	2	1
85. Lane selection	4	3	2	1
86. Speed maintenance	4	3	2	1
87. Remains in lane	4	3	2	1
88. Hesitates with reason only	4	3	2	1

At the roundabout, take the 1st exit.

89. Use of turn signals	4	3	2	1
90. Yields right of way	4	3	2	1
91. Turns when appropriate	4	3	2	1
92. Ability to follow instruction without reminding Y/N	4 -Y			1 - N

At the roundabout, take the 2nd exit

93. Use of turn signals	4	3	2	1
94. Yields right of way	4	3	2	1
95. Turns when appropriate	4	3	2	1

At the cross roads follow the sign for the Hospital

96. Identifying cross roads and locating road sign	4	3	2	1
97. Speed of processing	4	3	2	1

Pass the Hospital and take the next right into Lakelands

98. Road position from main road into minor road	4	3	2	1

Take the first right, followed by a left and then a right again

99. Ability to follow multiple step directions and sequencing skills	4	3	2	1

Find house No. 94

100. Ability to multitask and split attention skills	4	3	2	1
101. Completion of task safely	4	3	2	1

Return to Hospital

102. Retention of information and ability to recall	4	3	2	1

Park the car in a suitable parking space

103. Spatial awareness and securing the vehicle safely	4	3	2	1

TOTAL SCORE _______________

1. **Requirement for Driving Assistance**
   (i.e. instructor uses dual brake or steering wheel)**:** Yes ______ No ______

2. **Non-Standard Situation – Describe (i.e. hazard detection): -**
   ____
   ____
   ____
   ____
   ____

3. **Investigator's Global Judgement of Driving Safety:**
   Determine prior to calculation of total score above

   Occupational Therapist: **Safe** ______ **Unsafe** ______

   Driving Instructor: **Safe** ______ **Unsafe** ______

PART B **OPERATIONAL SKILLS**

Following completion of the driving route, rate driver on global performance of following operational tasks:

Control of steering	1	2	3	4
Control of accelerator	1	2	3	4
Control of brake	1	2	3	4
Control of clutch	1	2	3	4
Operation of gears	1	2	3	4
Use of gears	1	2	3	4
Use of turn signals	1	2	3	4
Use of wipers (if appropriate)	1	2	3	4
Overall control of car	1	2	3	4

TOTAL SCORE _______________

<u>PART C</u> **COGNITIVE SKILLS**

Following completion of route, transfer the scores from Part A to the following table. Each score should be entered in the blank space for that question. Total the scores from each column to determine the overall score for each cognitive domain.

Question	Attention	Planning	Decision Making	Memory	Self-Regulation
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

Question	Attention	Planning	Decision Making	Memory	Self-Regulation
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

Question	Attention	Planning	Decision Making	Memory	Self-Regulation
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					

Question	Attention	Planning	Decision Making	Memory	Self-Regulation
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					
88					
89					
90					
91					
92					
93					
94					
95					
96					
97					
98					
99					
100					
101					
102					
103					
TOTAL					

Min Score					
Max Score					
Percent Score					

ATTENTION/VIGILANCE

Refers to driver's ability to maintain attention on the task at hand, switch attention as needed, refocus to the task of driving, recognize potential hazards, and be aware of the traffic environment.

TOTAL SCORE ______________________

PLANNING

Refers to driver's ability to make appropriate adjustments to speed/position, inform other road users of manoeuvres, choose the correct road position, and divert route when required.

TOTAL SCORE ______________________

DECISION MAKING

Refers to driver's response to road signs, reaction to hazards, hesitation on the road, and choice of driving action to take.

TOTAL SCORE ______________________

MEMORY

Refers to driver's ability to recall instructions provided by instructor (working memory), the correct use of car operations, and their adherence to the rules of the road (motor & long-term memory).

TOTAL SCORE ______________________

SELF-REGULATION/CONTROL

Refers to driver's maintenance of the car's position on the road, speed regulation, and completion of driving manoeuvres.

TOTAL SCORE ______________________