EFFECTS OF AGE, EXPERIENCE AND TRAINING ON HAZARD PERCEPTION

by

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Ryerson University, 2013

A thesis

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Arts

in the Program of

Psychology

Toronto, Ontario, Canada, 2015

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Abstract

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Hazard perception (ability to identify dangerous road situations that require evasive action) declines with age and is linked to changes in visual attention and crash risk. Evidence shows that training can improve this ability in older adults. Yet, no study has considered the type of experience (manual versus automatic transmission) these older drivers have. The current study aims to fill this gap by examining the effects of age, experience and training on hazard perception ability. Twenty-four older and 23 middle aged adults (equal number of manual/automatic drivers per age group) were trained in a 20-minute single-session on hazard perception. Results indicate hazard performance declines with age and this is exacerbated with older automatic drivers. Further, the results show that generally training improves for most hazard variables. However, training does not assist older automatic drivers on identifying hazards.

Acknowledgements

First and foremost, I want to thank my advisors Dr. Maureen Reed and Dr. Lixia Yang. This thesis would not have been possible without their continued support, patience, and guidance. I also want to thank my committee members Dr. Todd Girard and Dr. Frank Russo for their invaluable comments.

I want to thank my family for their unwavering support and encouragement. I am forever grateful for your unconditional love and belief in me.

I want to thank my lab mates and friends in the psychology graduate program. It’s a privilege to work alongside you.

Finally, I want to thank the Ontario Graduate Scholarship (OGS) and Canada Graduate Scholarship Master’s (CGS-M) Social Sciences and Humanities Research Council (SHHRC) Award for funding this project.

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Effects of Age, Experience and Training on Hazard Perception

Overview

Hazard perception (ability to identify dangerous situations while mobile, e.g., driving or walking) declines with age (Quimby & Watts, 1981; Horswill et al., 2008; 2009). Yet, older drivers are the fastest growing cohort of drivers (Canada Safety Council, 2006). The primary focus of this project is to determine whether age and experience (e.g., manual versus automatic) affect hazard perception. The second focus of this study is to examine whether training improves hazard perception, and if so does the training benefit vary by age and experience. The third purpose is to examine whether hazard training improves performance on other visual attention tasks (i.e., Useful Field of View).

Hazard perception (while driving) is the ability to scan the road and foresee other road users that likely pose a threat to the safety of a driver (Horswill & McKenna, 2004). Hazard perception ability is typically examined in the lab using video based tests (e.g., Hoswill, Kemala, Scialfa, & Pachana, 2010). In these tests, a video of a real-world driving scenario is presented to a participant, shown from the point of view of a driver, in which several dangerous situations emerge throughout the course of a driving route. For example, as the driver moves along the route, a pedestrian may suddenly appear and approach the road, or another car may signal that they are merging into the lane directly in front of the driver. In these examples, both the pedestrian and the merging car ahead would constitute hazards, in that a hazard is defined as any other road users that may potentially require the driver to modify his or her driving (e.g., brake, slow down, or steer away) in order to avoid an accident or near accident. In a typical hazard perception test, the participant is instructed to press a response key (or touch the screen) as quickly as possible to indicate that a hazard is present, and the time from when the hazard first appears to the time when a response is made is recorded (Hoswill, Kemala, Scialfa, & Pachana, 2010; McKenna, Horswill, & Alexander, 2006). The response latencies across hazard trials are averaged for each participant to index hazard perception ability.

Horswill and colleagues (2008) found that the time to identify hazards is linked to changes in contrast sensitivity and visual attention ability in older adults. As well, declines in hazard perception ability amongst oldest old adults (i.e., ages 75+) compared to other adults (ages 35-74) are shown to be mediated by these same cognitive and vision variables (Horswill et al., 2009). Importantly, hazard perception ability is a skill related to crash risk (Horswill & McKenna, 2004; Horswill, Anstey, Heatherly & Wood, 2010). Thus, declines in attention and vision put older adults at increased risk of accidents because it takes them more time to identify and respond to dangerous situations on the road.

Changes In Vision With Age

Static acuity, contrast and dynamic acuity decline with age. For example, a longitudinal study by Bergman and Sjostrand (2002) followed older adults from the age of 70-97 and repeatedly tested their visual acuity using Snellen letter charts. Acuity in this instance was defined as the smallest letter size reliably identified by the participant. They found that normal acuity (≤ 20/25) was preserved in 86% of participants at the age of 70, 48% at 82, 24% at 88, 7% at 95, and no preserved acuity found among participants aged 97. These findings are consistent with those reported by others (Haegerstrom-Portnoy, Schneck & Brabyn, 1999; Van der Pols et al., 2000). Acuity and contrast losses occur due to changes in the optics of the eye and neural processes (Owsley, 2011). Optic changes include miosis (smaller pupil size) and issues with accommodation (ability to focus the lens of the eye; Owsley, 2011). Neural changes may be due to undersampling of visual inputs at the retinal or higher levels. It is thought that this undersampling may result from neural degeneration. In addition, acuity and contrast changes may be due to a noisy visual system, namely unrelated neural firing caused by the loss of myelin (Peters, 2002). In relation to driving, Owlsey and McGwin (1999) reviewed studies of driving performance and acuity, concluding that acuity is only weakly related to crash involvement.

Like visual acuity, contrast sensitivity (ability to distinguish grey versus black bars) is also found to decline with age (Owsley, Sekuler, & Siemsen, 1983), with 40-100% of older adults showing contrast losses (Reed, 2009). Moreover, these declines are greatest among oldest old than younger old adults (Rubin, 1994). For example, Rubin (1994) found that twice as many older adults above the age of 75 showed deficits in contrast sensitivity in comparison to those between the ages of 65-74. Thus, visual function losses that occur in older adulthood are significant, especially the marked declines observed amongst the oldest old adults. These losses are apparent even when acuity is preserved (Reed & Rowe, 2002). Most studies show only weak relationships between contrast sensitivity and crash involvement (US Department of Transport, USDOT, 1997). However, McGwin and colleagues (2000) showed that contrast acuity was predictive of driving difficulties in higher risk situations (e.g., high volume, night driving, left turns, and parking).

Dynamic acuity is the smallest object that can be detected during motion. Long and Crambert (1990) measured dynamic acuity across the lifespan, and noted that it declines with age, with those over the age of 60 showing poor dynamic acuity, which could be compensated for by increased luminance. These losses are not strongly related to crashes, as meta-analyses show a weak relationship between dynamic acuity and crash rates (USDOT, 1997).

Changes in Attention with Age

The Useful Field Of View (UFOV) is a part of the visual field where information can be processed quickly (at a glance). The UFOV is a three-part test probing the domains of processing speed, selective attention and divided attention. Edwards and colleagues (2006) examined the UFOV in older adults aged 65-94 and found significant declines with age. This is consistent with the results of Scialfa and Hamaluk (2001) indicating that older adults are less able to detect targets that are presented for less than 15 msec. Madden and Langley (2003) found that further losses are observed in older adults when detecting a target presented with distractors. The results presented thus far suggest that older adults have difficulty with their UFOV, and they are affected by quickly presented targets and by distractors. This might indicate that older adults will have great difficulty identifying hazards. The UFOV has already been shown to be associated with crashes, difficult driving maneuvers (e.g., left hand turns) and simulator driving performance (Ball et al. 1993; McGwin et al., 2000; Hoffmann, McDowd, Atchley, & Dubinsky, 2005; USDOT, 1997).

Changes in Hazard Perception with Age

In a simulated driving experiment with 60 drivers (ages 17-72), five of whom were above 65 years of age, Quimby and Watts (1981) examined the average time it takes for older adults to detect and respond to dangerous traffic situations. In this study, participants were seated in a car where they watched driving clips (presented from a driver's point of view) on a projected screen. The task required participants to adjust a lever to indicate both the detection of the hazard and its risk. On each trial the reaction time to detect the hazard was measured. Hazards included cars ahead abruptly braking to make a turn without signaling. The results indicated that older adults took more time to detect hazards than middle aged adults; however, the study had a small older adult sample size (n = 5 older adults). In a second study, Underwood and colleagues (2005) found few differences in the hazard perception of 12 middle aged (ages 30-45) and 12 older adults (aged 61-76). In this study, participants were instructed to monitor driving clips for driving hazards (dangerous situations requiring evasive action such as braking) and to press a response button as soon as a danger was detected. The accuracy (successful hazard detection) and speed (duration from hazard onset) of hazard identification was measured, and the eye movements of participants were recorded. Minimal age differences were found in visual search patterns, based on eye movements. Additionally, no age differences in accuracy or speed were found; however, older adults were twice as likely as middle aged adults to falsely identify hazards. The apparent conflict in these studies in terms of reaction time has been resolved in later studies using larger older adult sample sizes (Horswill et al., 2008; 2009).

Horswill and colleagues (2008) examined the hazard perception ability of 118 older adults aged 65-84. The results revealed that age is positivity correlated (r = 0.27) with hazard perception response latencies (reaction times), indicating that with increasing age, response to hazards becomes slower. Following up this study using matched groups (gender, education and vocabulary), Horswill and colleagues (2009), examined whether hazard perception latencies differed between middle aged (35-55), younger old (65-74) and oldest old adult (75-84) drivers. This study revealed that oldest old adults were significantly slower at responding to hazards (i.e., by 480 ms on average) compared to the combined average response times of the middle aged and younger old adult groups. These declines in hazard perception have significant real world consequences, given the established association between accident involvement and hazard perception latencies in the elderly population (Horswill, Anstey, Heatherly & Wood, 2010).

Driver Experience

Manual driving differs from automatic transmission driving because it requires a driver to carry out additional tasks on the road, such as gear shifting and operating the clutch. The additional steps make manual driving a far more attention resource-demanding task than automatic transmission driving, particularly for older adult drivers.

Selander, Bolin and Falkmer (2011) examined whether the number of driving errors made by older (aged 70-90) and middle aged adults (aged 27-48) differ in automatic versus manual transmission driving. The older adult sample consisted exclusively of participants who were currently licensed and driving manual transmission vehicles. In this study, all participants completed two driving tests on a fixed route, using both manual and automatic transmission automobiles. A driving evaluator was present in the vehicle during the tests to record the number of driving errors made in several categories, such as maneuvering and speed. The results showed that older adults made more overall driving errors in the manual compared to the automatic condition, whereas middle aged adults did not. As well, examinations of each driving error type revealed that older adults failed to maintain lane position more frequently in the manual compared to the automatic condition. They also made twice as many errors of driving too fast for the situation (i.e., they failed to drive at a reasonable speed given the road environment, despite being within the posted speed limit) in the manual compared to the automatic condition. These differences were not observed in the number of errors made by middle aged adults in the different transmission conditions. The findings suggest that gear shifting is highly resource demanding for older adults, and may leave less spare attention resources to be allocated towards other aspects of driving, such as maintaining lane position or monitoring changes in the driving environment so speed can be adjusted accordingly. Hazard perception search is an effortful task itself (Horswill & McKenna, 1999; 2004) and requires the driver to concurrently attend to multiple stimuli on the road (e.g., pedestrians, other cars ahead, traffic lights). Based on this and Anguera et al. (2013; see below) it is plausible that older manual drivers' experience/practice engaging in high attention demanding activities while driving may lead them to differ in their hazard perception ability, compared to older drivers with automatic driving experience. Further, it is plausible that both groups might differentially benefit from hazard perception training. It is expected that automatic and manual older drivers may differ in hazard perception latencies, and have the potential to benefit from training based on evidence showing that attention ability is modifiable through experience (i.e., training), even in older adulthood.

Driver Training

Driver training programs typically intend to improve driver knowledge, on-road/simulator performance, or cognitive processes (e.g., processing speed; Reed, 2014) related to driving. Kua and colleagues (2007) reviewed the effectiveness of driver training programs and found little evidence of their success in improving road performance. Knowledge based interventions usually involve older adults' self-assessment of driving abilities, education training of on road rules, and safe driving practices. Cognitive training interventions usually involve training on tests of processing speed and attention. It was shown that cognitive and knowledge training had little impact on actual road performance, though both provided some improvement in driver attention and increased avoidance of high risk driving situations, including improvement with dangerous driving maneuvers. Kua and colleagues (2007) also shows some limited effectiveness of on-road/simulator driver training. Older adults showed improvement in some hazard perception situations (e.g., left turns and intersections).

Hoswill, Kemala, Wetton, Scialfa, and Pachana (2010) trained the hazard perception of 11 older adults aged 65-94 in a single session (17 minutes). The researchers found that trained older adults (relative to an untrained older adult control group) showed small improvements in the speed at which they identified road hazards (i.e., an average of 513 msec. faster), following completion of training. Such improvements were not observed in the control group. However, in their small sample study they did not examine how driver experience relates to hazard perception ability or training benefits. Moreover, they did not examine the accuracy of hazard identifications because the paradigm used was designed such that all hazards would eventually be detected by the participant. Thus, it is not clear whether hazard perception training is associated with differential improvements in hazard identification speed and hazard perception accuracy for drivers with different driving experience (automatic vs. manual), or whether increasing age is associated with reduced hazard identification speed and accuracy when considering experience. Thus, further studies with larger sample sizes are needed to consolidate the results and to further examine interactions between age and driver experience on hazard perception ability and training effects. Moreover, the ecological validity of the hazard perception paradigm used by Horswill and colleagues (2010) is questionable, as they did not specifically measure what older adults identified as hazards (i.e., accuracy). Thus, it is unclear whether older adults were in fact detecting hazards accurately, as opposed to other stimuli that may have occurred concurrently. It seems plausible that the latter may be possible given the high rate of false alarms observed among the small sample of older adults in Underwood and colleagues (2005), in which older adults were twice as likely as middle aged adults to report false positive hazards. Studies with larger sample sizes are needed to directly examine the accuracy of older adults' hazard identifications.

Training Benefits Leading to Improvements on Other Tasks

Anguera and colleagues (2013) examined the benefits of training multitasking abilities using a driving related video game in older adults (aged 60-85). For this intervention, older adults were randomly assigned to one of three groups (control, single-task and multi-task).

Participants in the single and multi-task groups were required to play a video game for a total of 12 hours over a 1-month period (three 1-hour sessions per week). Those in the single-task group completed the two tasks of the game in isolation. One task was a perceptual discrimination task in which participants were instructed to detect a target sign, and the other was a visuomotor tracking task in which they used a joystick to keep a car centered in a continuously altering path. Those in the multi-task training group completed both tasks concurrently. The results of this study suggested that older adults in the multi-task training condition showed significant training-induced improvement in the multi-task, and they were able to maintain the benefits for 6 months following the intervention. Specifically, they showed a reduction in dual-task performance costs to the same level as the baseline of younger adults. Training gains resulting from the practice of dual-task for older adults in the multi-task training group was also shown to improve sustained attention and working memory. The findings demonstrate that practice at engaging in multi-tasking through a video game is an effective way to improve older adults' ability to perform high attention resource demanding activities, and that these benefits appear to generalize to other cognitive control related abilities.

Recently Casutt, Theill, Martin, Keller and Jancke (2014) provided older adults cognitive (selective attention and vigilance) or simulator training. They found that simulator training led to greater driving behaviour improvements (e.g., lane changes) than cognitive training, but that both types of training led to improvements in cognitive function. This suggested that driver training may improve driving performance and other non-trained cognitive abilities.

Gaps in the Literature

Given the similarities between the multi-tasking version game in Anguera and colleagues (2013) and the naturally occurring high resource demands that manual driving poses to older adults (i.e., older adults must attend to operating the vehicle [gear shifting] and attend to other driving aspects [e.g., monitoring the car ahead, traffic lights, or pedestrians]), it is likely that the real world practice and experience of manual driving may lead older drivers to demonstrate better hazard perception abilities than older automatic drivers. However, these finding also raise the possibility that gains from hazard perception training may be greater among automatic relative to manual drivers, as automatic drivers may have more room for improvement. But this remains speculative, since no published studies to date have examined the relationship between experience with different types of automotive transmission, hazard perception ability, and hazard perception training in older adults. The current study aims to fill this gap.

In addition, the literature has not sufficiently addressed the issue of whether training leads to improvements on other tasks. As described earlier, little evidence exists to support that cognitive or educational programs lead to improved driving in older adults, while limited evidence is available to support that driver training improves cognitive performance (Kua et al., 2007; Casutt et al., 2014). While Horswill and colleagues (2010) showed that hazard perception training for older adults resulted in improvements on an identical hazard perception task, they did not examine whether this lead to improvements on other visual attention tasks. The current study aims to fill this gap by examining whether driver training (hazard perception) also provides improvements on other visual attention tasks.

Moreover, the merit of brief training interventions has not been sufficiently addressed by the literature. All of the aforementioned training studies are multi-session and occur over several weeks (e.g., Anguera et al., 2013; Casutt et al., 2014) – aside from the 17 minute single-session training used in Horswill and colleagues (2010). Lengthy and onerous training programs are likely not feasible if they are to be offered on a wider scale publicly through agencies such as the

Ministry of Transport. This study will address this gap by evaluating the benefits of a brief 20-minute hazard perception intervention.

In summary, this study addresses the following main research questions: 1) Does age and experience affect hazard perception?; 2) Does training improves hazard perception, if so, does the training benefit vary with age and experience?; 3) Does training improve performance on other visual attention tasks? If so, does the training benefit vary with age and experience?

The Current Study

Method

Participants

Twenty-three middle aged (ages 35-55 years) and 24 older (ages 60 and above) adults participated in this study. All participants held a current valid Ontario driver's license. Each age group was divided into individuals who drive automatic and those who drive manual (12 manual and 12 automatic drivers per each age group) transmission cars. All participants included in the manual condition had driven manual transmission regularly within the past 10 years. Participants in the automatic condition typically drove with automatic transmission and each had not driven a manual vehicle regularly within greater than 10 years since time of testing. The mean age of middle aged automatic and manual drivers were 42.18 years (*SE* = 1.37) and 42.44 years (*SE* = 2.54), respectively. The mean age of older automatic and manual drivers were 76.90 (*SE* = 10.51) and 74.58 (*SE* = 9.59) respectively.

Older adults were recruited from the Ryerson Senior Participant Pool (RSPP), flyers posted on campus, word of mouth in the university community, and other individuals who had expressed an interest in participating in research who were not currently members of the Ryerson participant pool. Participants in the middle aged group were students recruited from the Ryerson Undergraduate Participant Pool, in addition to the methods outlined above. Middle aged adults from the undergraduate pool received 1.5 course credits towards their Introduction to Psychology course, as compensation for their involvement in this study. Middle aged adults who were not members of the undergraduate pool and all older adults received $20 as incentive for their involvement in this study. All participants were tested in the Vision Science Laboratory at Ryerson University.

Middle Aged Adults. There were no significant differences in the mean ages, years of experience, depth perception, and performance on the Useful Field of View subtests (speed of processing, divided attention, selective attention (all *p*s > 0.05) between middle aged automatic and manual drivers. Manual were found to have better visual and contrast acuity (both *p*s <.001) than middle aged automatic drivers. Please refer to table 1 for all sample characteristics data.

Older Adults. There were no significant differences observed in the mean ages, visual acuity, contrast acuity, years of experience, depth perception, and performance on the Useful Field of View subtests (speed of processing, divided attention, selective attention (all *p*s > 0.05) between older automatic and manual drivers.

Automatic Drivers. Older automatic drivers had poorer visual acuity, contrast acuity, and depth perception than middle aged automatic drivers (all *t*, *p*s < 0.05). They also had lower scores (took longer) on the selective and divided attention subtasks of the UFOV (both *t*, *p*s <. 05). These groups did not differ in processing speed (*t*, *p* = .16).

Manual Drivers. Manual older drivers had poorer visual acuity, contrast acuity (both *t*, *p*s <.001), and marginally poorer (*t*, *p* = .06) depth perception than middle aged manual drivers. These groups did not differ in their performance on the divided attention or processing speed UFOV subtasks (*p* > .05), but older adults had poorer performance (were slower) than their younger manual driver counterparts on the selective attention subtask (*p* < .01).

Materials

Pre-test and Post-test Hazard Perception Test. The hazard perception tests included 20 pre-test and 20 post-test video clips of driving hazards. 40 clips in total were created for these tests and were randomly assigned to two sets, each including 16 clips (with hazards) and 4 no-hazard clips. The clips were counterbalanced across participants. The time at which a hazard emerged in each clip varied between trials, with roughly an equal number of hazards presented during the start, middle and end of the clips. Test 1 included four pedestrian, four merging, three breaking, and five intersection hazards. Test 2 included four pedestrian, five merging, two braking, and five intersection hazards. In each test, four of the 20 clips acted as controls with no hazards present. These clips were used to measure false alarm rates. All clips were presented for a range of 4 - 29 seconds.

The clips were created by recording videos while driving through urban streets in the city of Toronto, which captured naturally occurring driving hazards, using a Go-Pro Hero camera. They were shot in a resolution of 1080 at a frame rate of 30 frames per second. All clips were shot from the driver's perspective.

Prior to the hazard perception tests, participants were provided with the task instructions and explained what a driving hazard is. A hazard was defined as a situation in which an accident or near miss between the driver and another road user (cyclist, pedestrian or other vehicle) might occur, unless an evasive action was taken (braking, slowing, or steering away). To help clarify the definition, three examples of what constitutes a hazard were provided. For example, participants were told that a car merging ahead of the driver is considered a hazard, as the driver may need to slow down to prevent a possible collision with this vehicle. Participants were instructed to identify the first hazard in each clip by pressing a button and then to verbally report what the hazard was. They were told that each clip may contain multiple, one, or no hazards, so they should only press the response button in the event that they believe a hazard is present, and do so as soon as they perceive the first hazardous situation developing. Clips were repeated if the participant failed to detect the hazard. This was done to give an opportunity to view the actual hazard if they falsely identified a hazard prior to it emerging in the clip. The time at which participants noticed a hazard, relative to the actual start of the hazard, was recorded for each clip. In addition, whenever a participant pressed the button, the clip was paused so the participant could verbally identify the hazard. A textbox appeared on the pause screen and was used by the experimenter to type in the participant's hazard identification response (identified what they believed to be the hazard). On trials with hazards present, the program measured hazard reaction times by recording the time elapsed between the onset of the hazard presentation and the response. When misidentifications occurred, the situation believed to be a hazard was recorded and participants were offered a second chance to view the hazard (and were told another hazard may be in the clip). The hazard tests were presented to participants on 21-inch monitor at a viewing distance of 57 cm.

Pre-Test and Post-Test Visual Attention Variables.

The Useful Field Of View (UFOV; Visual awareness Inc., 2002), a measure of the spatial area of where participants can be alerted (USDOT, 1997), was used to assess three sub-functions of visual attention: speed of processing (Task 1: identifying a target), divided attention (Task 2: identifying a target while concurrently performing another task), and selective attention (Task 3: identifying a target in the presence of distractors). In each of these tasks, the outcome measure is the time in msec it takes to detect a single object (a vehicle: truck or car) at the center of a screen (Task 1); while concurrently identifying the location of a target in the periphery (Task 2; see figure 2); or while identifying the location of a target in the periphery that is surrounded by non-targets (Task 3; see figure 1). The UFOV tests were presented to participants on 17-inch monitor at a viewing distance of 24 inches.

Static Visual Acuity was assessed using the 96% contrast (black on white) Reagan Eye Chart (Paragon Services Inc.; see figure 2). Participants were required to read rows of letters (eight letters per row) as they decrease in size with every row (as they move from the top to the bottom of the chart). Participants read the letters on the chart aloud until they were no longer able accurately identify six or more letters within a single row. The size of smallest line of letters participants could accurately identify with 75% accuracy was used to provide an acuity score on this test. This score was then converted to a Snellen equivalent score that reflects the participants score relative to the standardized population scores. For example a score of 20/20 indicates the normal population sees at 20 feet what the participant can only resolve from 20 feet. A score of 20/10 means that the normal population sees at 20 feet what the participant can only resolve from 10 feet. Numbers recorded in table 1 only show the numerator score since all Snellen equivalents have a 20 in the denominator.

Contrast acuity was assed using the 11% contrast (grey on white) Reagan Eye Chart (Paragon Services Inc.; see figure 3). This test followed the same procedure and standardized score conversion as the visual acuity test described above.

Depth perception was assessed with the Stereo Fly Test/Graded circle test (Stereo Optical Co; see figure 4). The test consists of pictures taken with polarizing film, such that when wearing polarized glasses (each eye polarized orthogonally), some aspects of the picture appear to float above the others. Wearing 3 dimensional (3D) glasses, participants identified which aspect of the picture (one of four circles) sits above the others. In this task, the aspect of the picture that floats above the others (the target circle) consists of two overlapping images with a disparity that results in the image being perceived as a 3D object. In each successive image trial, the depth of the 3D target circle decreased (i.e., the disparity between the two images got smaller). Thus, this task assessed the smallest disparity in arc seconds (ranging from 40 to 800) that can accurately elicit a depth response, where 40 arc seconds represents the better depth ability.

Participant Driving History Form. The participant driving history form collected information on the following: (1) the participant's history of manual and automatic transmission driving; (2) the number of years they have been driving manual and/or automatic transmission; (3) the last time they drove manual and/or automatic transmission; (4) whether they currently drive a vehicle with manual and/or automatic transmission; (5) whether they currently own a vehicle with manual and/or automatic transmission; and (6) the number of overall years they have been driving.

Hazard Perception Training Intervention. The hazard perception training intervention was created using 14 unique video clips (i.e., different from the clips used at pre- and post-test) depicting common hazards, including cyclists, pedestrians, following a car, cars entering the roadway, and oncoming traffic (at intersections). Six of the clips were used for the training segment and eight were used for practice. A hazard was present in each of the six clips used for the training segment. In the practice segment, a hazard was present in six of the clips and the remaining two clips were controls (no hazard present). All the clips were created by filming hazards that occurred naturally while driving throughout urban streets in the city of Toronto, using a Go-Pro Hero camera. The training session was administered to participants on a 21-inch monitor at a viewing distance of 57 cm.

Procedure

Upon arrival, participants received payment or course credit for attending the session. Informed consent was then collected from participants. After providing consent, the participant was seated 10 feet away from the vision charts, where contrast (11% grey font on a white background) and visual acuity (96% black font on a white background) was measured.

Participants' depth perception was then measured using the Stereo fly/Graded circle test. After participants completed the vision screen measures, participants were seated at a desk with a 17-inch monitor computer. The UFOV pre-tests (processing speed, divided attention, and selective attention) were conducted at this computer at a viewing distance of 24 inches. The pre-test for hazard perception was completed using either test 1 or test 2 described above. The hazard perception tests were counterbalanced such that all odd participant numbers completed test 1 first and test 2 at post-test, whereas all even numbered participants completed test 2 first and test 1 at post-test. This was followed by a 20-minute hazard perception training session. In this session, participants were shown six clips of hazards, in which the hazard was identified and an explanation of why it is a hazard was given. The experimenter specified when the hazard started in each clip and why caution needs to be taken, e.g., "notice that the car directly ahead of you has just braked, and continued to break such that you need to break. The moment their brake light was detected they became a hazard because you were required to slow and then stop to prevent a collision with this vehicle." After the viewing of the six training clips, participants were given opportunities for practice on eight similar clips and provided with feedback by the experimenter. Participants were given the opportunity to practice on each clip once. They practiced identifying the hazard in six hazard-present clips and two hazard-absent clips. Participants were told if they correctly identified the hazard in the hazard-present clips. Participants were also told if they were correct in identifying that no hazard was present in the hazard-absent clips. If participants failed to correctly identify the hazard or that no hazards was present on the first viewing, they were asked to watch the clip again. When hazard trials were viewed for a second time, the experimenter identified the correct hazard when it emerged in the clip, and explained why it was a hazard possibly requiring evasive action to avoid danger. As well, in cases where participants had misidentified a hazard on the first trial, the experimenter explained why the misidentified hazard (what the participants incorrectly believed was a hazard) was not in fact one. When hazard-absent trials were viewed for a second time, the experimenter explained why the misidentified hazard (what the participant believed to be a hazard) was not in fact a hazard. Once training was completed, participants were given the hazard perception test (either test 1 or test 2 depending on counterbalance assignment) followed by the UFOV post-tests. Participants were offered a break partway through the testing session, and encouraged to take breaks as needed. After the completion of all tasks, participants were debriefed on the purpose of the study

Analysis

Hazard Perception Performance. The three independent variables of this analysis are age (middle aged vs. older adults), driver experience (manual vs. automatic transmission) and training (pre vs. post). The three dependent variables are hazard perception identification mean times, precision and the number of correctly identified hazards. For each of the three dependent variables, the main analyses employed a 2 (age) ×2 (experience) × 2 (training) mixed model ANOVA, with age and experience as between-subjects variables, and training (pre vs. post) as a within-subjects variable, as presented in figure 5.

UFOV Performance. The three independent variables for this analyses were age (middle aged vs. older adults), driver experience (manual vs. automatic transmission) and training (pre vs. post). The three dependent variables are the UFOV processing speed, divided attention, and selective attention scores (speed to identify vehicle in msec). The main analyses employed a 2 (age) ×2 (experience) × 2 (training) mixed model ANOVA, with age and experience as between-subjects variables, and training (pre vs. post) as a within-subjects variable, as presented in figure 5.

Demographic Analyses. Means and standard errors were calculated for all the screening tests (visual acuity, contrast perception, and depth perception) by age (middle aged vs. older adults) and driver experience (manual vs. automatic).

Correlational Analyses. Independent correlations were conducted on vision variables with hazard identification mean times, precision and number of correct identifications at pre-test for each age by experience driver group.

Results

Data Analysis Overview

The results were analyzed using SPSS 18 software and are presented in three sections. The first section presents the results on hazard perception performance (mean times, precision, and number of correct identifications). The second section presents the results on UFOV performance (processing speed, divided attention, and selective attention). The third section presents the results of the follow up correlational analyses. The same 2 (age) ×2 (experience) × 2 (training) mixed model ANOVA, with age and experience as between-subjects variables, and training (pre vs. post) as a within-subjects variable was conducted on the dependent variables in the hazard perception and UFOV performance analyses. The false alarm analysis for hazard performance is not reported since no significant effects or interactions were revealed by the 2 (age) ×2 (experience) × 2 (training) mixed model ANOVA on the number of falsely reported hazards.

Hazard Perception Performance

Mean Times of Correct Hazard Identifications. The analysis conducted on the time of hazard detection (i.e., from the time of hazard onset to the time a detection response was made) is presented in Figure 6. The analysis includes only the instances (i.e., hazard trial clips) where the participant correctly identifies the hazard. This analysis revealed a significant main effect of age, slower responses in older (*M* = 2.71, *SE* = .17) relative to middle-aged adults (*M* = 2.08, *SE* = .18), $F(1, 43) = 6.51$, $p = .02$, $\eta_p^2 = .13$, see figure 6-7. The training effect was also significant, $F(1, 43) = 4.42$, $p = .04$, $\eta_p^2 = .09$, with longer correct hazard identification time pre-training (*M* = 2.59, *SE* = .18) relative to post-training (*M* = 2.20, *SE* = .13), suggesting training-induced benefit (see figure 8). All the other effects were not significant (ps $\geq .05$).

Number of Correct Hazards Identified. The analysis conducted on the number of hazards correctly identified is presented in figure 9. This analysis revealed a significant main effect of age, older adults (*M* = 8.88, *SE* = .35) correctly identified fewer hazards relative to middle-aged adults (*M* = 10.31, *SE* = .36), $F(1, 43) = 8.32$, $p < .01$, $\eta_p^2 = .16$, see figure 9. The training effect was also significant, $F(1, 43) = 44.64$, $p < .001$, $\eta_p^2 = .51$, with fewer correct hazard identifications pre-training (*M* = 8.19, *SE* = .36) relative to post-training (*M* = 11.00, *SE* = .28), suggesting training-induced benefit (see figure 9). These main effects were qualified by a trend towards a significant 3-way interaction between age, experience and training ($F(1, 43) = 3.00$, $p = .09$, $\eta_p^2 = .07$) and a trend towards a significant 2-way interaction between age and training ($F(1, 43) = 3.73$, $p = .06$, $\eta_p^2 = .08$), which are depicted in figure 9. These analyses were followed up with a 2 (age) x 2 (training) mixed ANOVA within each driver experience group. The results revealed a significant age by training interaction for automatic ($F[1, 22] = 9.51$, $p < .01$, $\eta_p^2 = .30$) but not manual drivers, $F(1, 22) = .015$, $p = .90$, $\eta_p^2 = .00$. Simple effects analyses revealed that manual older and manual middle aged adults did not significantly differ in the number of correctly identified hazards at pre-test, $F(1, 22) = .82$, $p = .37$. These groups also did not differ at post-test, $F(1, 22) = 1.42$, $p = .25$. The difference in performance by age group between manual drivers at pre-test and post-test is depicted in figure 10a. Simple effects analyses suggested that the number of correct identifications does not significantly differ between older automatic and middle aged automatic drivers at pre-test, $F(1, 23) = .10$, $p = .75$. However, post-training, older automatic drivers correctly identify fewer hazards than middle aged automatic drivers ($F(1, 23) = 24.24$, $p <.001$) which is depicted in figure 10b. Additionally, follow up simple effect analyses indicated the total number of hazards correctly identified for all groups improved (i.e., increased) with training (*p*s < .05) except for the older automatic group that showed no improvement from training ($F(1, 11) = .80$, $p = .21$). All the other effects were not significant (*p*s ≥ .05).

Precision of Hazard Identifications. The analysis conducted on the precision of hazard detection (i.e., internal variability in response time within each participant) is presented in figure 11. The analysis includes only the instances (i.e., hazard trial clips) where the participant correctly identifies the hazard. This analysis revealed a significant main effect of age, poorer precision (i.e., more variable from trial to trial) in older ($M = 1.55$, $SE = .14$) relative to middle-aged adults ($M = 1.13$, $SE = .13$), $F(1, 43) = 4.72$, $p = .04$, $\eta_p^2 = .10$, see figure 12, and based on figure 11 it is driven by the contributions of older automatic drivers. The training effect was also significant, $F(1, 43) = 5.04$, $p = .03$, $\eta_p^2 = .11$, precision was poorer pre-training ($M = 1.51$, $SE = .14$) relative to post-training ($M = 1.17$, $SE =.10$), suggesting training-induced benefit for all participants (see figure 13). Additionally, a trend towards a significant main effect of experience also suggested that manual drivers ($M = 1.17$, $SE = .14$) tended to be more precise than automatic ($M = 1.51$, $SE = .14$) drivers overall, $F(1, 43) = 3.17$, $p = .08$, $\eta_p^2 =.07$. All the other effects were not significant (*p*s ≥ .05).

UFOV Performance

Visual Attention Processing Speed. The analysis conducted on mean times for UFOV processing speed is presented in figure 14. This analysis revealed a significant main effect of age, older (*M* = 17.25, *SE* = .71) had slower processing speed than middle aged adults (*M* = 15.17, *SE* = .71), $F(1, 42) = 4.31$, $p = .04$, $\eta_p^2 = .09$, see figure 15. The training effect was also marginally significant (see figure 16), UFOV processing speed tended to be slower pre-training (*M* = 17.15, *SE* = 1.00) relative to post-training (*M* = 15.27, *SE* = .16) for all participants, $F(1, 42) = 3.34$, $p = .08$, $\eta_p^2 = .07$, and this effect is driven by the improvement of the older adults, which is depicted in figure 14. All the other effects were not significant (*p*s ≥ .05).

Divided Visual Attention. The analysis conducted on mean times for UFOV divided visual attention is presented in figure 17. This analysis revealed a significant main effect of age, older (*M* = 52.89, *SE* = 6.78) were slower than middle aged adults (*M* = 17.25, *SE* = 6.78), $F(1, 42) = 13.81$, $p = .001$, $\eta_p^2 = .25$, see figure 18. The training effect was also significant (see figure 19), slower responding during divided visual attention tasks pre-training (*M* = 45.86, *SE* = 8.33) relative to post-training (*M* = 24.28, *SE* = 3.59) for all participants, $F(1, 42) = 6.40$, $p = .02$, $\eta_p^2 = .13$. These main effects were qualified by a significant age by training interaction, $F(1, 42) = 5.54$, $p = .02$, $\eta_p^2 = .12$ as depicted in figure 17. Simple effects analyses indicated that older adults were significantly slower than middle aged adults at pre-training ($F(1, 45) = 10.56$, $p < .01$) and post-training ($F(1, 45) = 4.68$, $p <. 05$). Regardless of the difference, the graph (figure 20) indicates that the interaction is due to improvement from the older adults at post-training. All the other effects were not significant (*p*s ≥ .05).

Selective Visual Attention. The analysis conducted on mean times for UFOV selective visual attention is presented in figure 21. This analysis revealed a significant main effect of age, older (*M* = 169.93, *SE* = 12.89) were slower than middle aged adults (*M* = 57.60, *SE* = 12.89), $F(1, 42) = 37.95$, $p = .001$, $\eta_p^2 = .48$, see figure 22. All the other effects were not significant (*p*s ≥

.05).

Vision & Hazard Perception

Other studies have shown that hazard perception is linked to vision in older adults (e.g., Horswill, 2008). Correlations between vision variables and pre-training hazard variables were examined in each of the four driver groups (older automatic, older manual, middle aged automatic, middle aged manual) to determine whether the association between vision and hazard perception varies by age and experience. The correlations between vision variables and hazard variables are presented in table 2.

***Visual Acuity*.** Mean times, precision and number of correctly identified hazards were not significantly related to the visual acuity of each age by experience driver group (ps $\geq .05$).

***Contrast Acuity*.** Mean times, precision and number of correctly identified hazards were not significantly related to the contrast acuity of each age by experience driver group (ps $\geq .05$).

***Depth Perception*.** Mean times and number of correctly identified hazards were not significantly related to the depth perception of each age by experience driver group (ps $\geq .05$). Further, precision was not significantly related to depth perception of all age by driver experience groups (ps $\geq .05$), except for the older automatic group ($r = .693$, $p = .01$, n = 12). This indicates that poorer depth perception (higher scores) is linked to poorer precision (increasing internal variability) in older automatic drivers.

Discussion

Age, Experience and Training Related Differences in Hazard Perception Abilities

Age. It was hypothesized that middle aged adults would outperform older adults in their hazard perception prior to training. The results of the present study confirm this hypothesis with the observed data indicating that older adults have slower mean response times and poorer precision (greater internal variability) relative to their middle aged counterparts. The observed results can be explained by the findings of studies that show the effects of limited cognitive resources on hazard perception ability, such as those of Savage and colleagues (2013). In this study, younger adults were assigned to detect hazards in driving clips under condition of high (solving a mental puzzle, e.g., what has six legs but only walks on 4) versus no workload (no puzzle). It was found that hazard identification reaction times and false alarms significantly increased in the high compared to the no workload condition. Similar evidence of slower reaction times to road hazards under dual-task / high workload conditions have been observed by others (Alm & Nilsson, 1994; Horrey & Wickens, 2006). Some evidence (e.g., Strayer & Drews, 2004) has even shown that dual-task conditions (phone conversation while driving) significantly slows the reaction times of younger adults such that it is equivalent to those of older adults under single-task conditions (drive only). Thus, these studies seem to suggest that limited attention resources underlie older adults' poorer performance on hazard identifications.

Losses in visual attention with age are well documented in the literature (Madden & Langley, 2003; Scialfa & Hamaluk, 2001). Edwards and colleagues (2006) observed age related decline on all UFOV subtests in a sample of 2759 older adults (aged 65-96). Losses in dual attention (indexed by performance on subtest 2) were pronounced in this sample, with average identification speeds observed to increasingly slow with each successive 5 years of life, past the age of 65 (i.e., 97 msec for adults ages 65-69, 115 msec at 70-74, 154 msec at 75-79, 192 at 80-84, 268 msec at 85+; *mean times only include older adults with a total 12 years of education, n = 785). Consistent with these losses, older adults in the present study were found to have poorer performance than middle aged adults on all three measures of visual attention. Importantly, pre-test performance on two of these measures (selective and divided visual attention) was significantly related to precision and mean times to identify prior to training. Thus, these observed correlations offer further support for a limited attention resource capacity to account for the poorer hazard abilities observed among older adults in the present study. This is in line with previous studies that show UFOV measures of visual attention predict the hazard perception abilities of older adults (Horswill et al., 2008; 2009).

While the exact biological mechanisms are unclear, it seems likely that age related structural, functional and neurochemical changes (e.g., dopaminergic or myelin abnormalities) that contribute to attention losses/a limited resource capacity in older adulthood, in turn impairs older adults' hazard perception abilities (Moss et al., 1999; Gunning-Dixon & Raz, 2003; Makris et al., 2007; Backman et al., 2010; Beste et al., 2012; MacDonald et al., 2012). Ziegler and colleagues (2010) examined age differences in white and grey matter using high resolution magnetic resonance imaging (MRI) and diffuser tensor imaging (DTI) scans in a large sample of young and older adults. Performance on measures of cognitive control (i.e., Trail Making Test (A-B score; Reitan, 1958), Wechsler Memory Scale-III Backward Digit Span (Wechsler, 1997b), Stroop Interference Test (Stroop, 1935), Controlled Oral Word Association Test (COWAT; Benton and Hamsher, 1989) among other cognitive abilities were also assessed. It was found that reduced functional anisotropy in frontal white matter was associated with increasing age, and poorer performance on cognitive control tasks was independently predicted by fractional anisotropy (FA) in frontal lobe white matter (i.e., FA in the left and right prefrontal cortex was predictive of the cognitive control composite score). Based on these findings, the authors concluded that the frontal lobes are integrally involved in the cognitive control abilities of older adults, and that age related declines in cognitive control are likely caused by degenerative processes that affect the integrity of white matter underlying the connections of frontal neural networks. Similar evidence of cognitive dysfunction related to age related frontal white matter degeneration has also been observed in older primates, including impairments in executive function (e.g., Moss et al., 1999; Makris et al., 2007). These findings suggest that frontal white matter integrity may possibly also relate to age related changes in hazard perception, given the established relationship between hazard perception and attention/control processes.

In addition to changes in white matter, age related changes in dopamine may possibly underlie the slower reaction times and greater internal variability of hazard identifications observed among older adults in the present study. Evidence demonstrates significant losses in dopamine associated with age and changes in dopamine has been linked to deficits in dual tasking (Backman et al., 2006; 2010; Beste et al., 2012). MacDonald and colleagues (2012) examined dopamine D1 densities in several brain regions along with mean response times and intra-individual variability (intra-individual standard deviation; ISD) on control and interference trials of the Multi-Source Interference task (MSIT) in young and older healthy adults. Older adults were slower than younger adults and were found to be more variable in the interference but not the control condition. In the interference condition only, increasing ISDs were found to be associated with increasing age and decreasing D1 binding in the anterior cingulate gyrus, dorsolateral prefrontal cortex, and parietal cortex (brain regions of the attention network recruited by the MSIT task). These findings led the authors to conclude that increased internal variability observed among older adults, under conditions that place demands on executive control, may be due to impaired dopamine modulation. Given that hazard search is effortful and also places demands on executive control, age related changes in dopamine is another plausible mechanism which may account for the poorer precision (greater internal variability) observed among older adults in the present study.

It is suggested that age related myelin losses and changes lead to diminished connections in neural networks and reduced neural conduction velocity (because the axons in which signals are being transmitted are poorly insulated by myelin), which disrupts the timing of neural circuits and results in a noisy system (Peters, 2002). Further, Backman and colleagues (2010) suggests that losses in dopamine decreases signal to noise ratio in neural networks, and this increased neural noise results in consequences such as less distinct neural representations of perceptual stimuli and increased interference and altered interactions between perceptual and neural noise, among other negative effects. Consequently, increased neural noise impairs the cognitive processing of older adults by slowing responses and increasing internal variability. Taken together, it seems plausible that poorer connectivity and increased neural noise resulting from myelin and dopamine losses also underlies the slowing of responses and enhanced internal variability observed in older adults' hazard abilities. Specifically, older adults are slower and less precise because they experience greater difficulty attending to hazards, due to the hazards neural representation being less distinct, and its signal more difficult to attend to among a high level of noise (concurrent unrelated activity). Again, this is speculated to occur due to impaired neuromodulation and poorer insulation of signals being transmitted in networks presumed to be implicated in hazard search (i.e., frontal regions).

Experience & Training. It was hypothesized that older automatic and manual drivers may differ in their hazard perception abilities and show differential improvements as a result of training. Further, it was hypothesized that all participants would improve as a result of training, but the degree of improvement may differ depending on the age by driver group.

The data in the present study indicates older but not middle aged adults showed training induced improvements in mean response times. In contrast, training improves the overall precision and the number of correct identifications for all participants. Experience was also found to affect certain aspects of hazard perception and training induced improvements. Manual drivers were observed to be marginally more precise than automatic drivers regardless of age. However, these differences were largely driven by the poorer precision of older automatic adults, who are least precise at pre-training and at post-training relative to the other three driver groups. Further, the data indicated that older automatic drivers were the only driver group who did not show improvements in the number of correctly identified hazards as a result of training. Several reasons may account for these findings.

Older but not middle aged adults showed training related improvements in their mean times to identify hazards. It is likely that middle-aged adults did not show faster times as a result of training since they were already incredibly quick in their hazard identifications at pre-test and are known to be the safest driver group (Reed et al., 2014). On the other hand, older adults were found to have slower mean response times relative to middle-aged adults prior to training, which was linked to their losses in attention. Pre-test mean times significantly related to divided attention UFOV scores at pre-test. The results suggest that training older adults in new ways to scan the road for dangerous situations, and opportunities to practice this skill while given feedback resulted in their faster identifications at post-test. Analyses examining the effects of training on UFOV variables indicate that older adults showed significant improvements in divided attention as a result of training. These findings indicate that older adults show training related improvements in their mean identification response speed because training compensates for their losses in attention, by enhancing their scanning abilities under conditions of distraction.

The marginal improvements in precision for manual compared to automatic drivers, regardless of age, is likely due to manual drivers continuous practice at engaging in the more effortful task of manual driving. In their daily lives, manual drivers must allocate attention resources towards pedestrians and other roads users to keep safe and avoid hazardous situations, while also allocating resources towards gear shifting and operating the clutch. Thus, hazard search in the present study is likely less resource demanding for manual drivers because participants did not have to gearshift during the hazard test. It is speculated that this lowered task difficulty leaves more available resources to allow manual drivers to be more precise (less variable) in their identifications.

Older automatic drivers show evidence of poorer precision at pre-test and at post-test. This group is likely less precise in their hazard identifications due to increased task difficulty. That is, older automatics are more variable in identifications because the task places greater demands on their resources, which are already limited due to age related losses. Further, motion related deficits might also partially contribute to the poorer precision of older automatic drivers. Depth is only shown by correlation analysis to be significantly related to the pre-training precision of the older automatic group. Given that depth and motion share the same mechanisms (Anzai, Ohzawa, & Freeman, 2001), it raises the possibility that motion mechanisms are breaking down in older adults, making their identifications more variable. Despite evidence that manual and automatic older drivers may experience similar motion losses (depth perception did not significantly differ between older automatic and manual drivers), these losses do not translate to equivalent impairments in precision between both groups due to the differential demands of the hazard task. Specifically, manual older drivers are more precise because the task is less complex for them, thus they are able to compensate for their motion losses unlike older automatic drivers.

Older automatic drivers were the only group who did not improve in their number of correct identifications as a result of training. This is likely being driven by their poorer precision. This is supported by correlations that show poorer precision is significantly associated with their fewer correct hazard identifications at pre-test.

Overall, the findings indicate that hazard perception can be improved in older adulthood with training, and that improvements are linked to the training compensating for age related attention losses. Additionally, the findings suggest that experience with manual driving benefits hazard perception, particularly in older adulthood. Evidence shows that practice engaging in visuomotor activity similar to gear shifting while concurrently searching for targets enhances attention ability and is associated with altered neural activation in the brain (Anguera et al., 2013). Thus, it is possible that lifelong practice with manual driving also leads to brain related changes that affect certain aspects of hazard perception. Given that driver experience affects precision (which in turn affects the number of correct identification) but not mean times in the present study, it seems possible that dopamine related mechanisms might underlie experience related differences. Age related losses in dopamine more strongly influence internal variability relative to mean response times, when the task is executively demanding (MacDonald et al., 2012). Thus, it is speculated that driver experience may mediate age related dopamine losses, such that age related losses are fewer in manual drivers, thereby allowing them to be less variable in their hazard identifications and more amenable to training (can improve their number of correct identifications).

Training Induced Improvements to other Tasks of Visual Attention

The results of the present study indicated that older adults show improved processing speed and divided visual attention after completing a single session of hazard perception training. Middle-aged adults did not show such improvements. It is likely that the lack of improvements observed among middle-aged adults is due to ceiling or near ceiling effects at baseline. That is, middle-aged adults were already incredibly fast at subtests 1 and 2 of the UFOV, thus had little room to improve as a result of training. In contrast, the improvements observed in older adults UFOV performance is likely due to changes in attention that results from hazard training. That is, processing speed and divided visual attention abilities are enhanced by learning new ways to scan the road for hazards, and practice at this executively demanding activity.

Evidence shows that older adults can improve on executively demanding tasks with practice, and that these benefits can transfer to other untrained tasks (Bherer et al., 2005; 2008; Lustig et al., 2009; Anguera et al., 2013). It is hypothesized by some that when improvement on a trained task shows evidence of transfer to an untrained similar task, it occurs because both tasks share a common underlying process (Lustig, Shah, Seider, & Reuter-Lorenz, 2009). For example, Dahlin and colleagues (2008) trained younger adults for 5 weeks on updating of working memory. In training, participants completed the letter memory task and 5 other tasks that similarly engage updating. The letter memory task requires participants to listen to lists of letters (which vary in size) and report back the last four letters when the list stops. The researchers found that transfer (from improvements on the letter memory task) only occurred for an untrained task (the n-back) that similarly recruits brain regions and engages the same process (i.e. updating) as the trained task (letter memory). In contrast, transfer did not occur for the untrained Stroop task that did not involve updating or striatal activation similar to the trained task. Based on these findings, it seems likely that the observed improvements in UFOV resulting from hazard training occur because both tasks require concurrent attention to multiple sources of information, and the participant must scan for and rapidly identify a target amidst distraction. Thus, both tasks likely engage the same processes and brain regions allowing for transfer to occur.

It is possible that the hazard training transfer effects on UFOV performance observed in the present study are due to motivational effects. That is, participants may have shown improvements in UFOV post-training, because they give more effort due to expectation that hazard training should lead to improvement on similar type tasks in the UFOV. However, motivational influences should have similar effects on all participants and consequently result in improved UFOV performance for all four of the experimental driver groups at post-test, which was not the case in the present study. Thus, it seems that motivational effects are unlikely the cause of transfer training effects in the present study.

Limitations

Given that a control group was not included in the present study, further research is needed to confirm that the training gains observed, and potential transfer effects of training to UFOV performance, are due to training and not simply practice effects. It is unlikely that gains related to hazard training are due to practice given that similar training related improvements (i.e., improved mean times of identifications) have been observed in studies that do include a control group (e.g., Horswill, 2015). In contrast, it is unknown whether the observed UFOV improvements post-training are due to hazard training or practice effects since no previous study has examined the effects of hazard training on UFOV performance. Some evidence does suggest that the improvements in UFOV are not due to practice effects because middle aged adults did not show improvements on the UFOV tasks when they had room for improvement (e.g., their average score on the divided attention task was a score of 18 msec which was close to but did not reach ceiling (a score of 14 msec). Regardless, a confirmatory experiment with an untrained control group will be conducted to follow up on this issue specifically

Additionally, it is possible that self-selection bias may account for the results of the present study, in that older adults who have greater difficulty detecting hazards are those who switch from manual to automatic driving, and therefore account for the poorer hazard perception abilities observed among the older automatic drivers. However, the influences of self-selection are likely minimal since the automatic older driver sample in the present study had driven with automatic transmission for an average of the last 41.63 of 57.42 years of their total driving experience. Further, nearly all the automatic older drivers learned how to drive using manual transmission (10 out of 12). Thus, it seems possible that these drivers switched over from manual to automatic due to other reasons, such as the increased availability and popularity of automatic transmission vehicles in Canada since the time at which they first became licensed. Future research comparing the hazard abilities of older adults who only have manual versus automatic driving experience would be beneficial in resolving this potential confound.

Conclusions

Overall the present thesis offers further evidence to support that the hazard perception abilities of older adults can be improved with training (Horswill et al., 2010; 2015), in just a brief single session. In the earlier training program designed by Horswill and his research team, training consists solely of participants passively watching video clips of hazards with voice over of a driving expert who explains how they would scan the road for potential hazards with little engagement or practice offered to the participant. Their newer training program also uses a taped instructional video with voiceover, but participants are given practice generating their own explanations of anticipated hazards on practice clips. The clip in then replayed with expert voiceover commentary identifying how to properly scan the road, and what is anticipated to be a hazard. Training in the current study differs from these programs in that no instructional video with voiceover commentary is used. Participants are shown filmed clips of driving where the experimenter explains what hazards are through example clips, and demonstrates ways to scan the road to better identify potential hazards. Participants are allowed to ask questions throughout any part of the training session. Further, participants being trained in the present study do not have to compare their prior commentary to a taped voiceover to receive feedback on their progress. Immediate and customized feedback is given by the experimenter throughout the training and addresses the specific errors or confirms correct identifications as they occur. Despite these differences, the data shows that older adults still show improvements in the present study.

The current study also differs from the previous training studies by Horswill and colleagues (2010, 2015) since it uniquely examines the effects of hazard training on the internal variability and number of correct identifications, in addition to hazard training transfer effects to UFOV performance. The results offer novel evidence that hazard training in older adults may lead to transfer effects to other untrained tasks of visual attention (e.g., improved divided visual attention). In addition, it provides novel evidence that driver experience may affect certain aspects of hazard perception (e.g. precision) and potential improvements that result from training this ability in older adults (e.g., manual but not automatic older drivers can be trained to identify more hazards correctly).

Future Directions

Existing research provides evidence for the role of cognitive factors in the impaired hazard perception abilities of older adults, such as Horswill and colleagues (2008) who demonstrates that UFOV performance is highly predictive of mean times to identify hazards. Yet, the biological mechanisms remain unknown. Future research should attempt to elucidate these mechanisms, by investigating the contribution of age related structural, functional and neurochemical changes to declines in hazard perception that occur with age. For example, the relationship between hazard perception abilities and age related differences in frontal white matter integrity, or age differences in dopamine binding potential whilst completing hazard tests seems likely to be a fruitful area of exploration that may offer useful insights. Future research might also assess the mediating role of driver experience on the possible biological underpinnings of hazard perception.

Enhancing our understanding of hazard perception, including shedding light on the biological mechanisms of age related declines and the factors that potentially mediate it (e.g., experience), is likely to offer tremendous safety benefits to all road users. For instance, a primary benefit is that this knowledge can aid the design of more effective training interventions for elderly drivers, and ones that tailor to the specific training needs of certain driver groups (e.g., older manual versus automatic drivers). Doing so is critical given that older drivers are on the rise and have higher crash rates (per mile driven), and their crash risk is predicted by their hazard abilities.

Tables

Table 1
Sample Characteristics

	Middle Aged		Older Adults	
	Automatic	Manual	Automatic	Manual
N	12	11	12	12
Age[1]	42.92 (2.43)	42.73 (2.54)	76.25 (2.54)	74.58 (2.43)
Visual acuity[2]	15.63 (1.04)	12.36 (0.58)	22.79 (3.00)	20.58 (1.48)
Contrast acuity[3]	24.36 (2.02)	18.11(1.57)	44.45 (8.68)	34.00 (3.23)
Depth perception[4]	49.17 (4.83)	43.63 (4.44)	130.00 (34.25)	110.00 (31.86)
Speed of processing[5]	15.36 (0.36)	15.18 (0.11)	20.67 (3.96)	16.92 (1.25)
Divided attention[6]	20.00 (4.50)	16.90 (0.51)	89.82 (24.33)	53.33 (22.98)
Selective attention[7]	72.73 (14.5)	48.33 (11.71)	184.45 (20.74)	166.67 (33.64)
Total years driving	22.67 (2.71)	24.36 (2.36)	57.42 (2.27)	55.92 (2.26)

Note. Standard Errors are presented in parentheses.
1. years, 2&3. Snellen equivalent, 4. Seconds of arc, 5-7. ms

Table 2

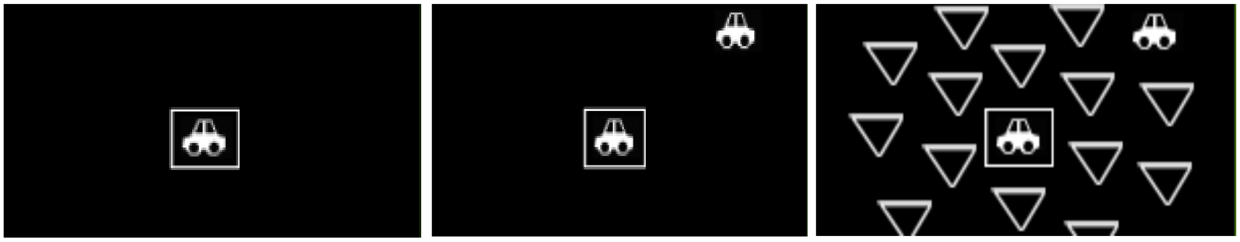
Correlations between Vision Variables and Hazard Variables at Pre-test

	Mean Time	Precision	Number of Correct Identifications
Visual Acuity			
Manual older	.47	.11	-.31
Automatic older	-.01	.15	-.50
Manual middle aged	-.41	-.42	.14
Automatic middle aged	-.00	-.16	-.14
Contrast Acuity			
Manual older	.16	.20	-.37
Automatic older	-.16	-.01	-.38
Manual middle aged	-.41	-.46	.30
Automatic middle aged	-.18	-.03	-.50
Depth Perception			
Manual older	.27	.05	-.03
Automatic older	.39	.69*	-.33
Manual middle aged	-.35	-.28	.45
Automatic middle aged	.22	-.09	-.07

Note. Correlations are presented for older manual (n=12), older automatic (n=12), middle aged manual (n=11) and middle aged automatic (n=12) participant groups.

*$p < .05$

Figures



1 2 3

Figure 1. Sample images of UFOV subtests 1-3, respectively

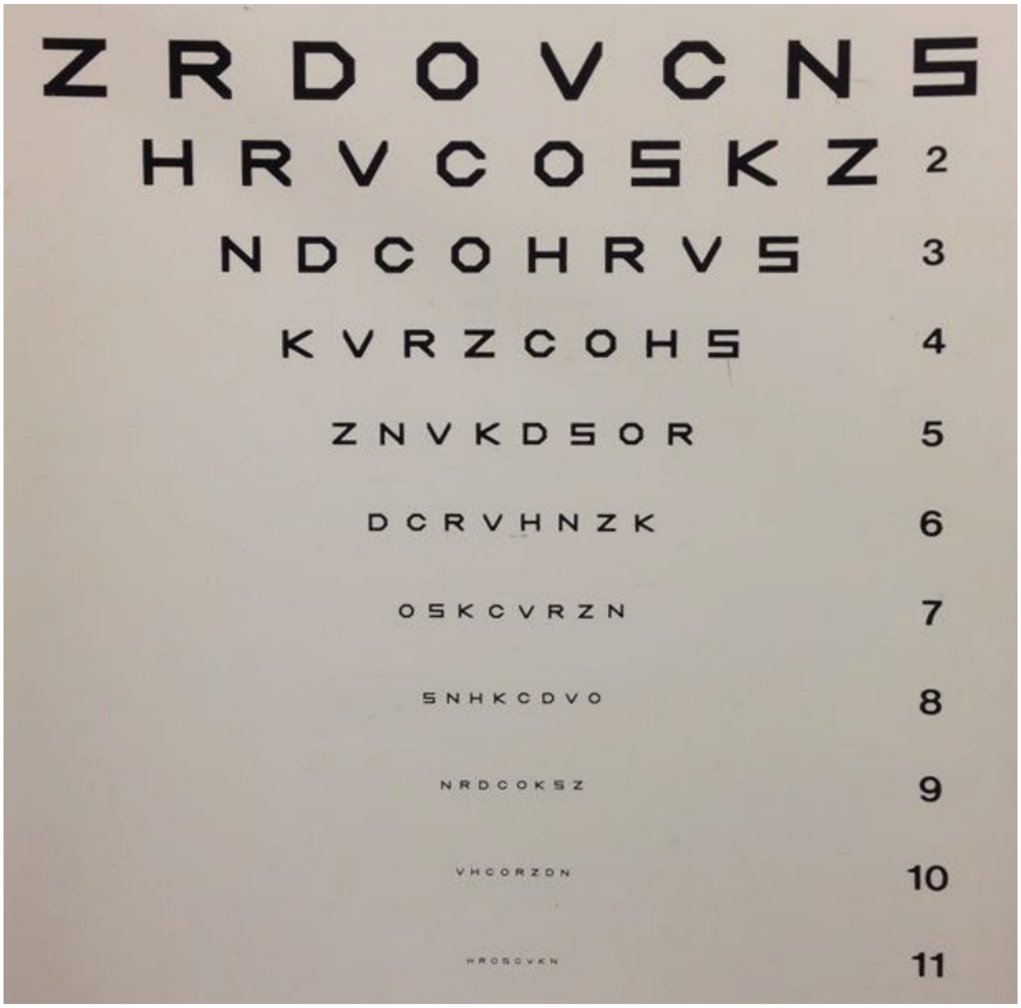


Figure 2. 96% Contrast Reagan Eye Chart

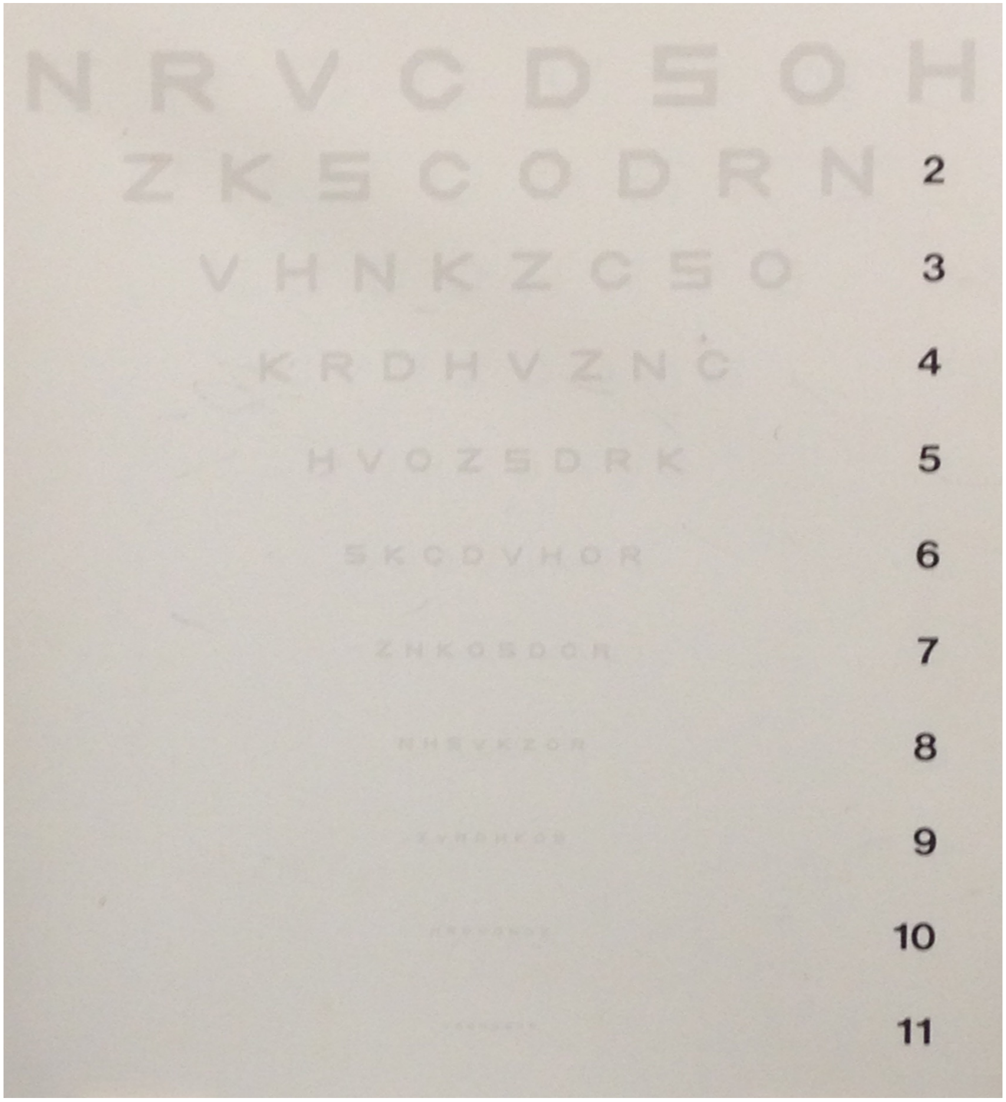


Figure 3. 11% Contrast Reagan Eye Chart

Figure 4. Stereo Fly Test/Graded Circle Test

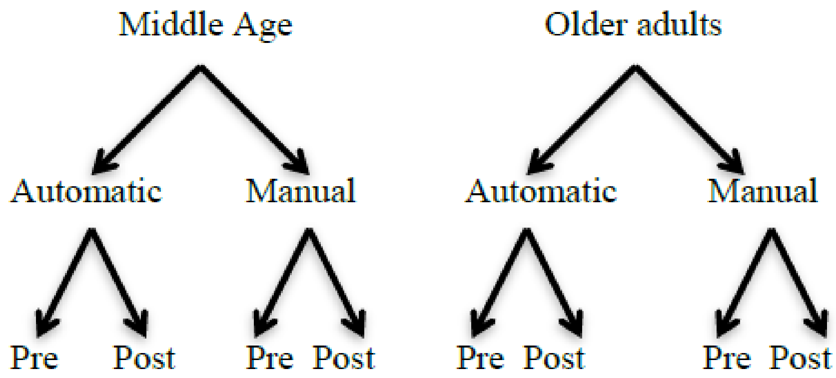


Figure 5. Diagram of the 2 (age) ×2 (experience) ×2 (training) mixed model ANOVA

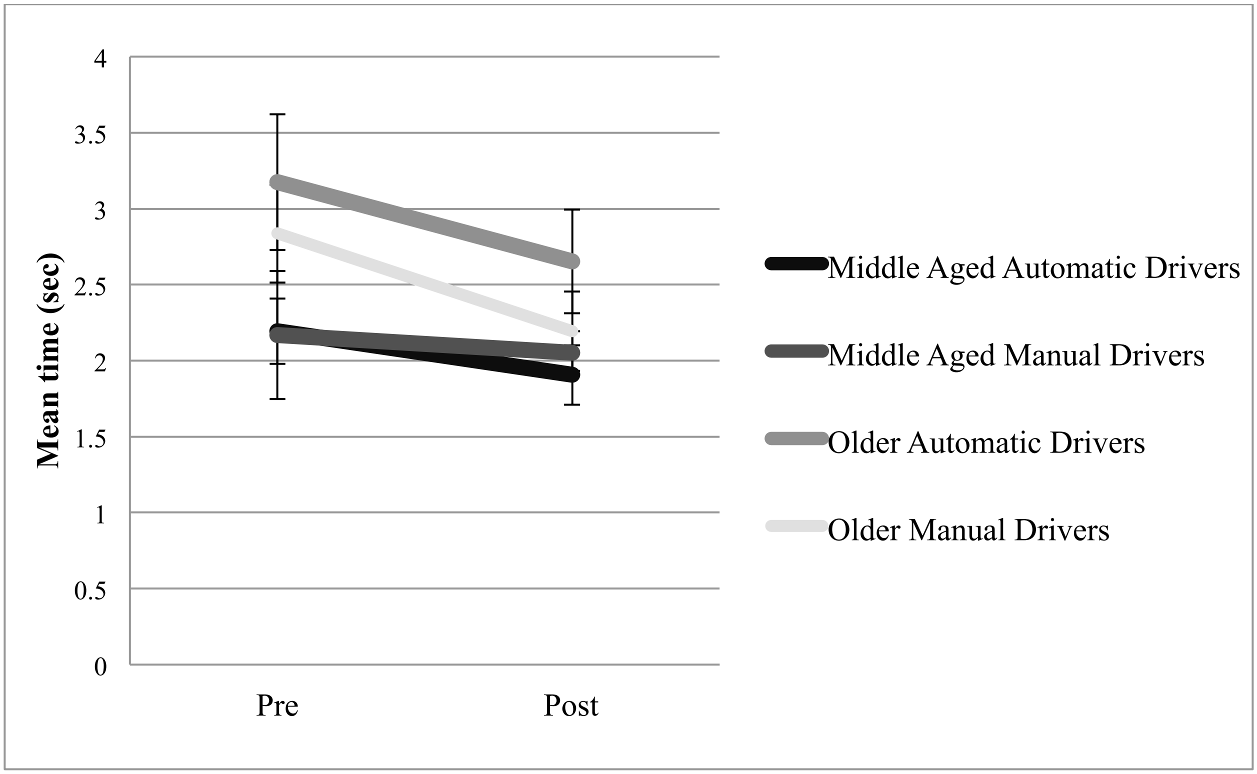


Figure 6. Mean times to identify hazards correctly by age and experience group. Error bars represent standard errors.

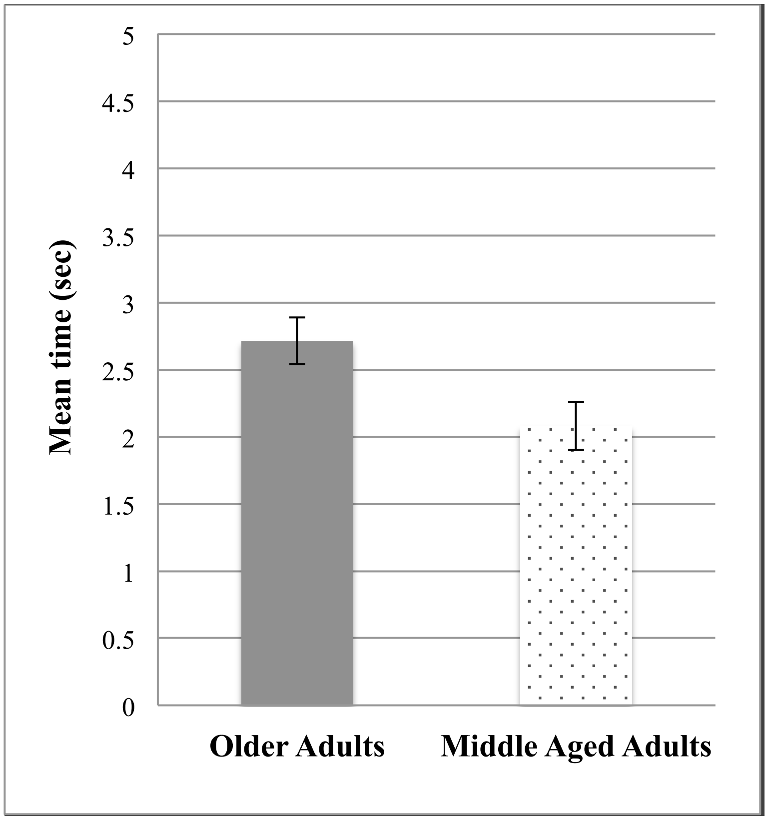


Figure 7. Main effect of age on mean time to identify hazards. Error bars represent standard errors.

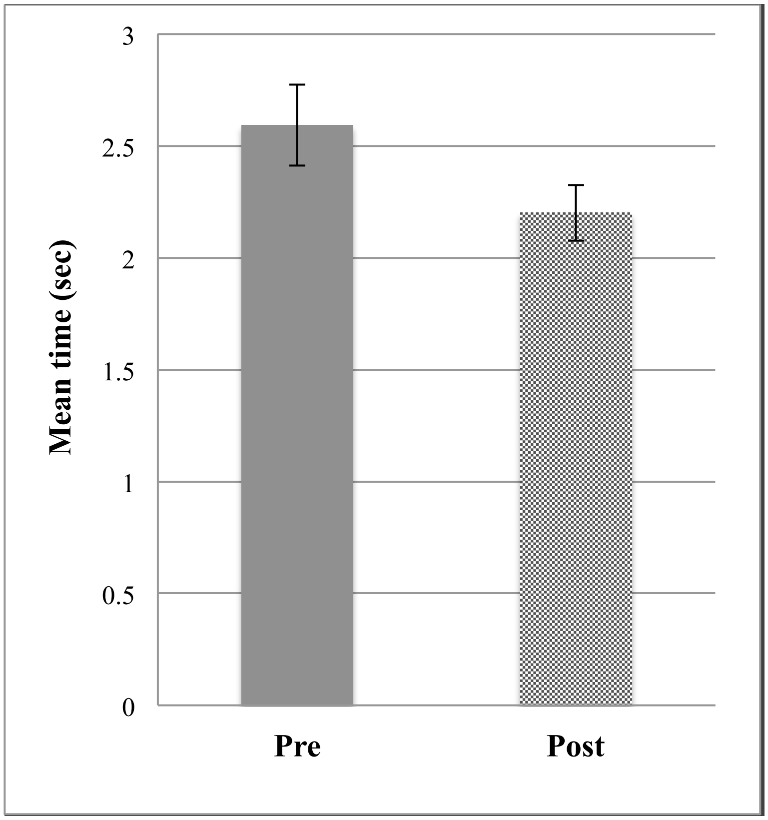


Figure 8. Main effect of training on mean time to identify hazards. Error bars represent standard errors.

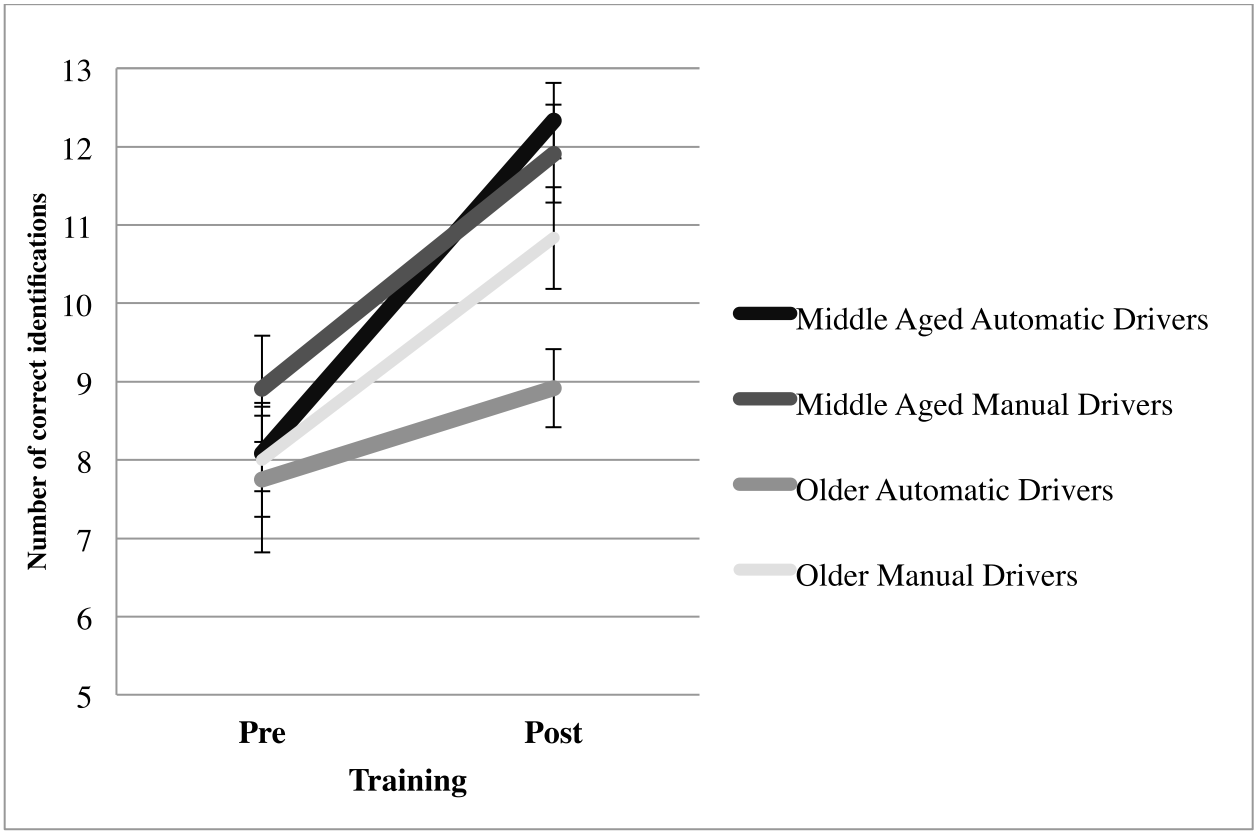


Figure 9. Mean number of correct identifications for each age by experience group. Error bars represent standard errors.

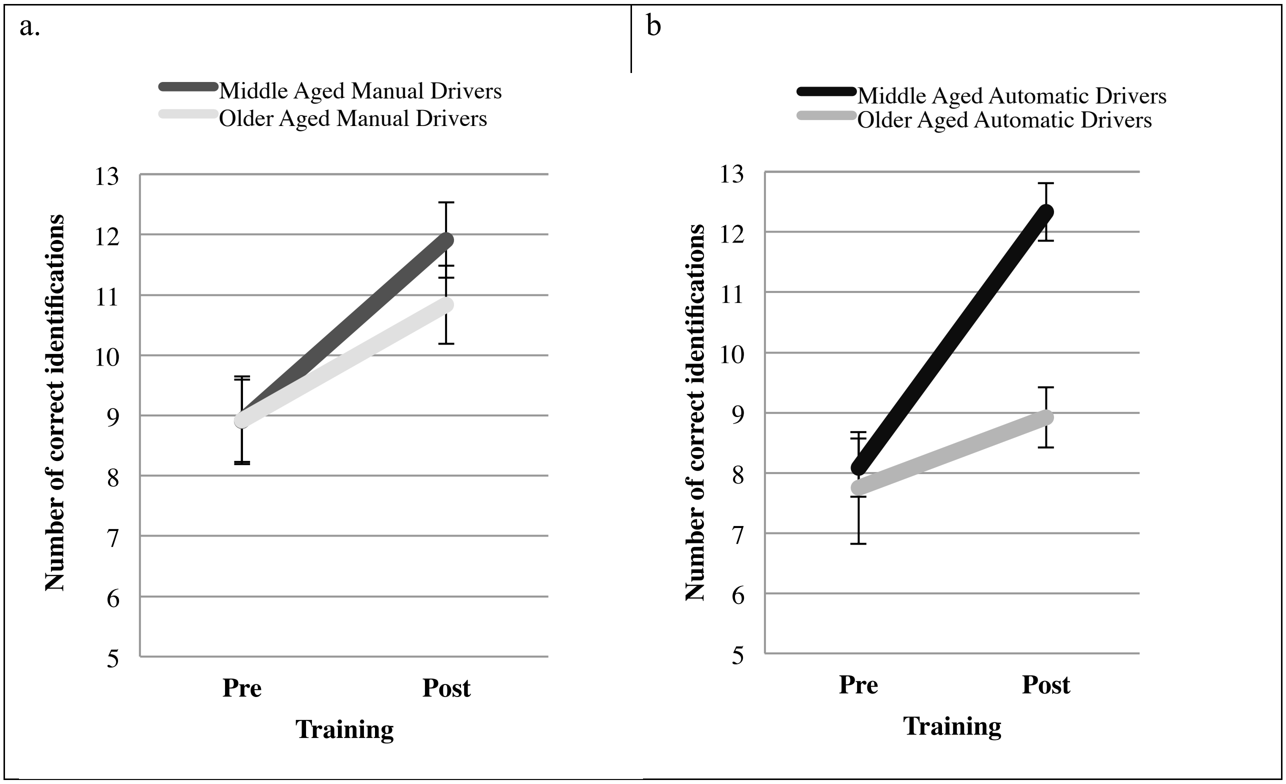


Figure 10. *a.* Mean number of correctly identified hazards (hits) of older and middle aged manual drivers at pre- and post-training; *b*. Mean number of correctly identified hazards (hits) of older and middle aged automatic drivers at pre- and post-training. Error bars represent standard errors.

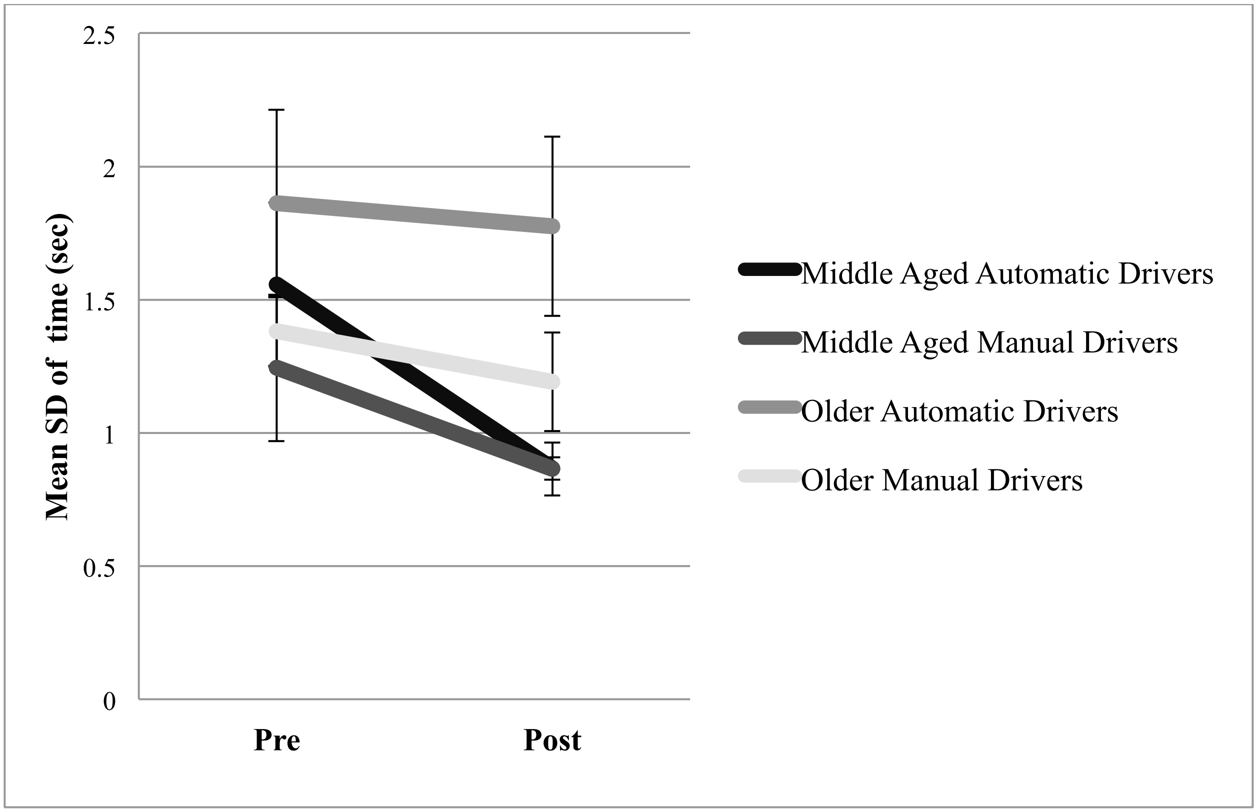


Figure 11. Mean internal precision in time for correct hazard identifications. Error bars represent standard errors.

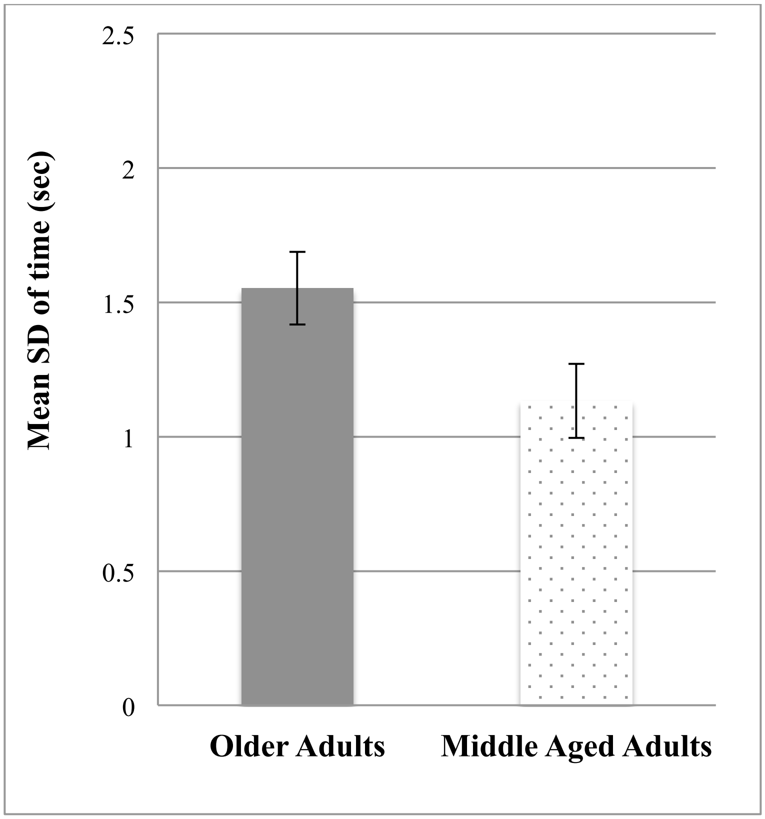


Figure 12. Main effect of age on internal precision of correct hazard identifications. Error bars represent standard errors.

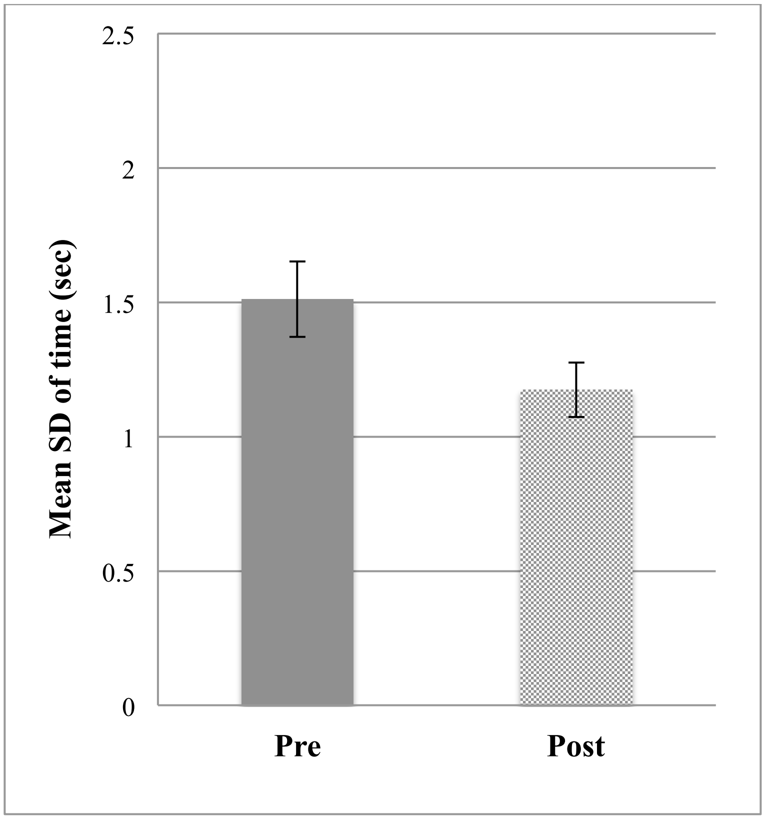


Figure 13. Main effect of training on internal precision of correct hazard identifications. Error bars represent standard errors.

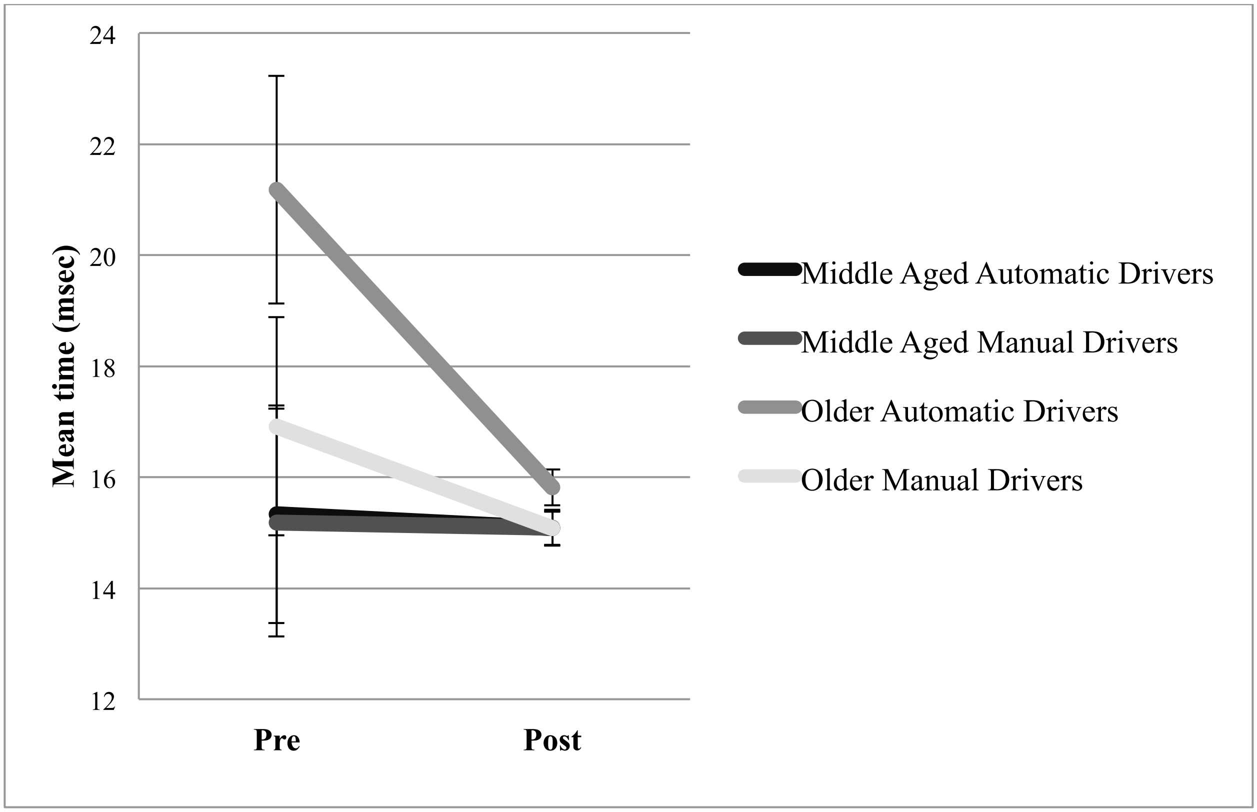


Figure 14. Mean times (msec) for UFOV processing speed by age group and experience driver type group. Error bars represent standard errors.

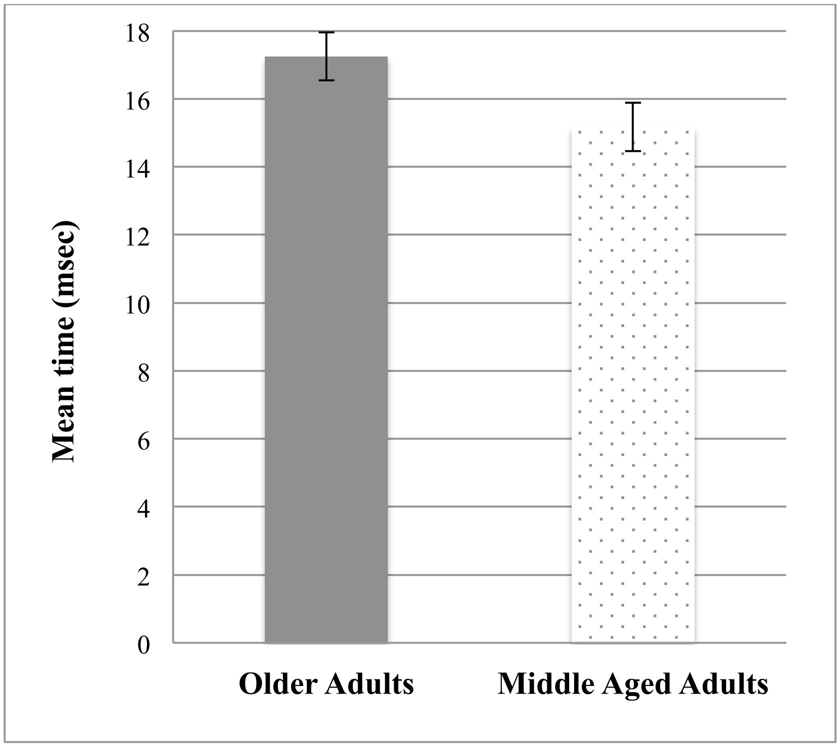


Figure 15. Main effect of age on UFOV processing speed. Error bars represent standard errors.

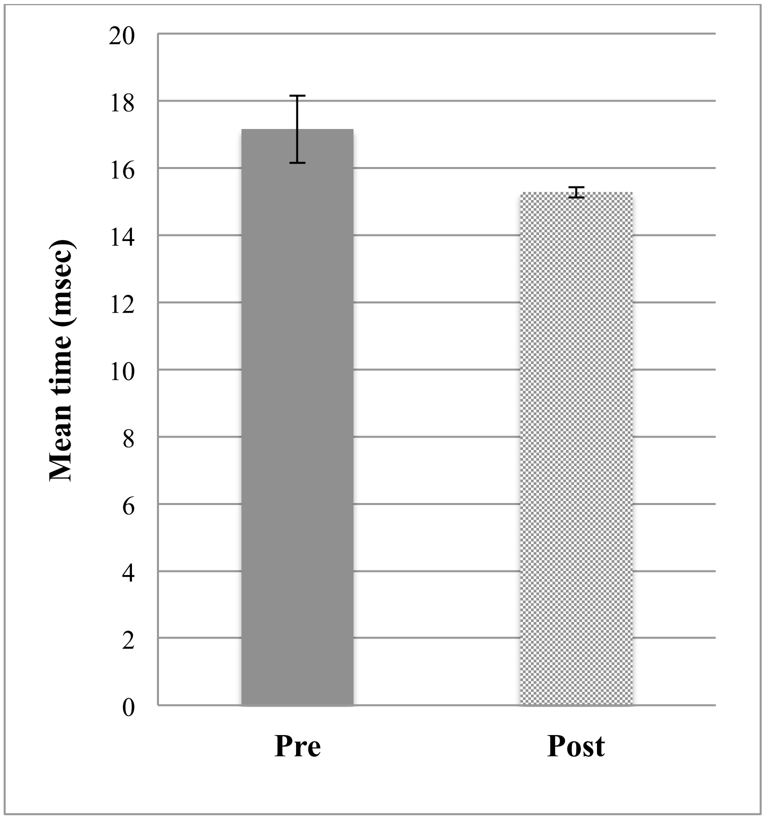


Figure 16. Marginal effect of training on UFOV processing speed. Error bars represent standard errors.

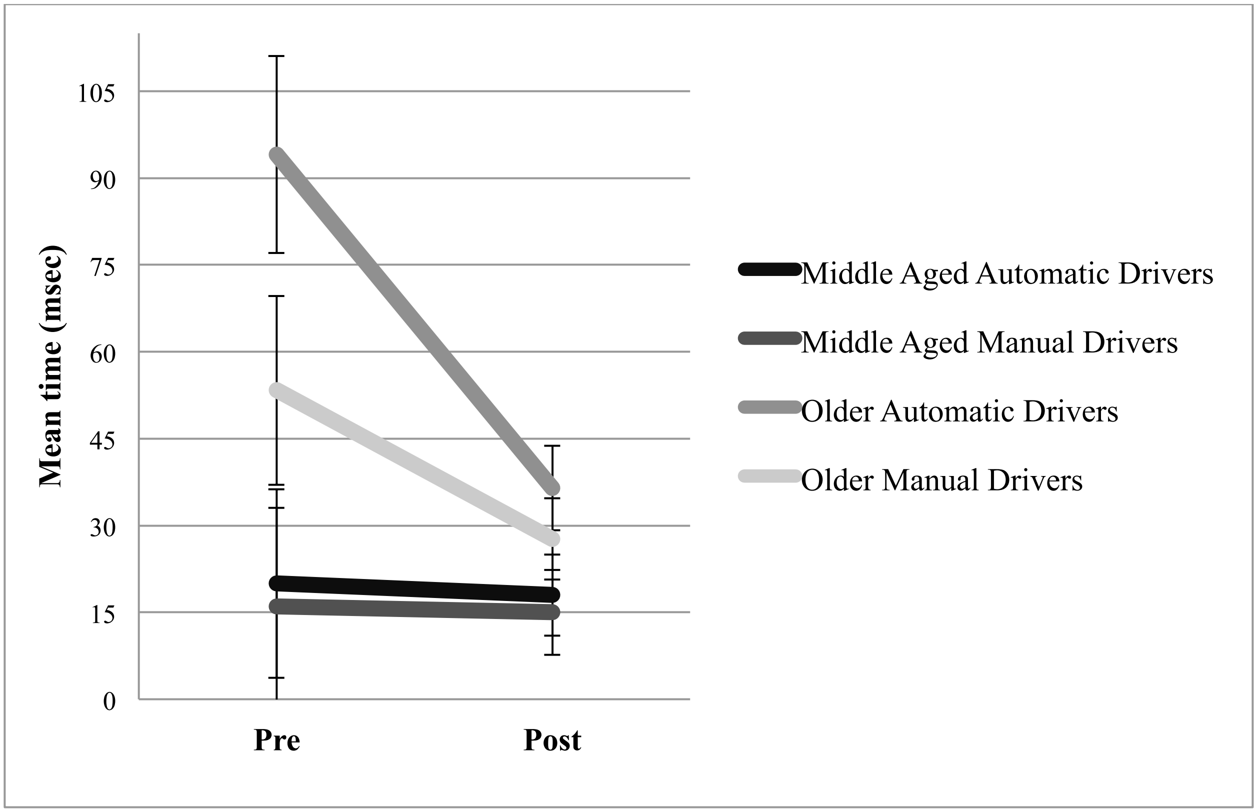


Figure 17. Mean times (msec) for UFOV divided visual attention by age group and experience driver type group. Error bars represent standard errors.

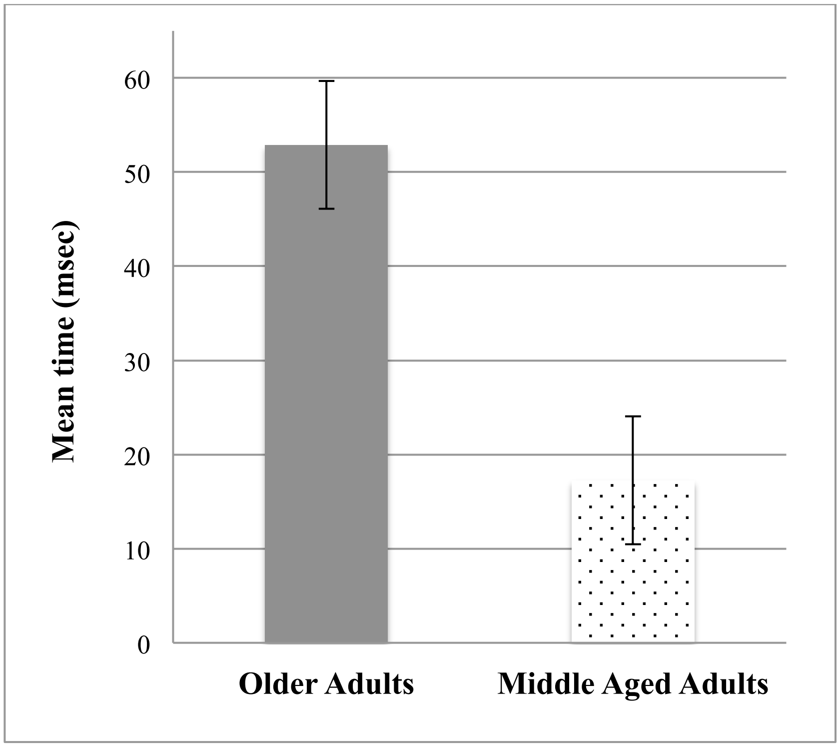


Figure 18. Main effect of age on UFOV divided visual attention. Error bars represent standard errors.

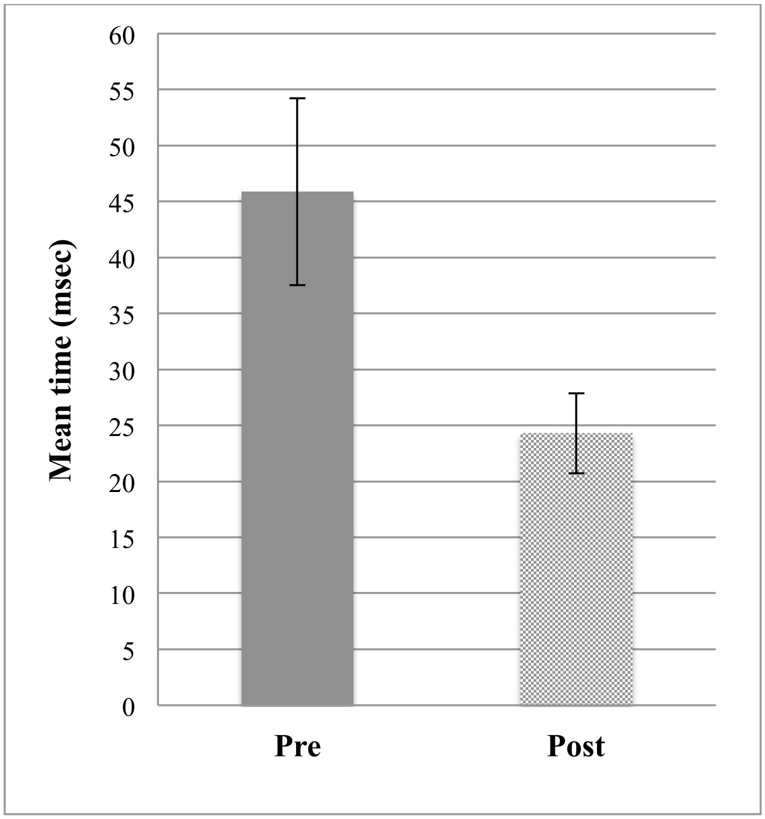


Figure 19. Main effect of training on UFOV divided visual attention. Error bars represent standard errors.

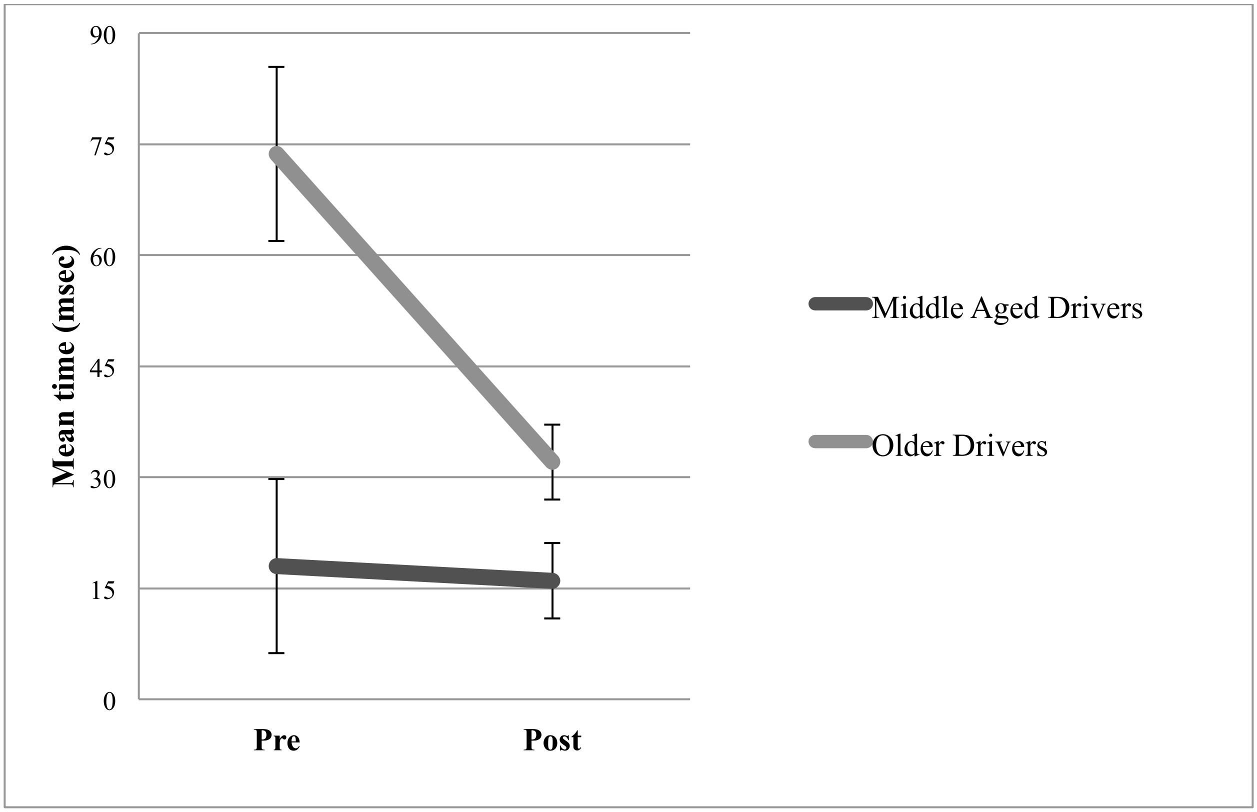


Figure 20. Age by training interaction on UFOV divided attention. Error bars represent standard errors.

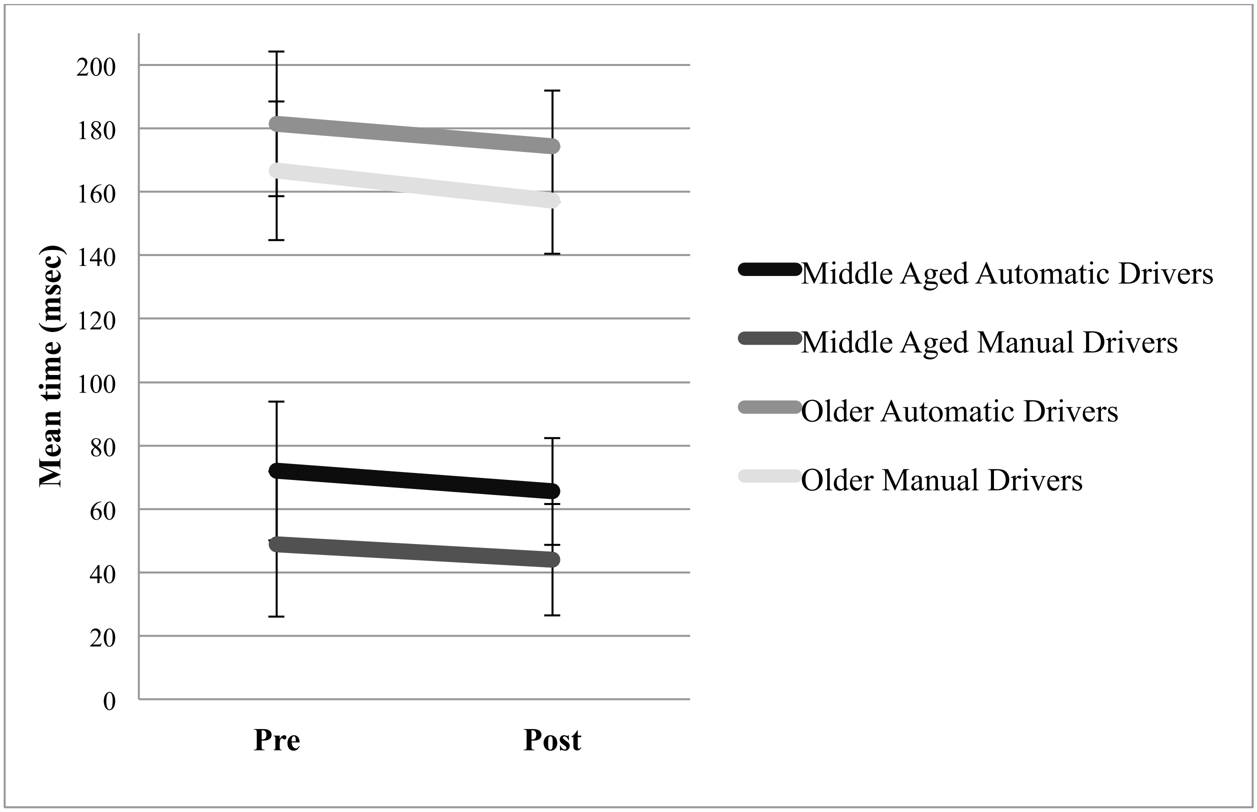


Figure 21. Mean times (msec) for UFOV selective visual attention by age group and experience driver type group. Error bars represent standard errors.

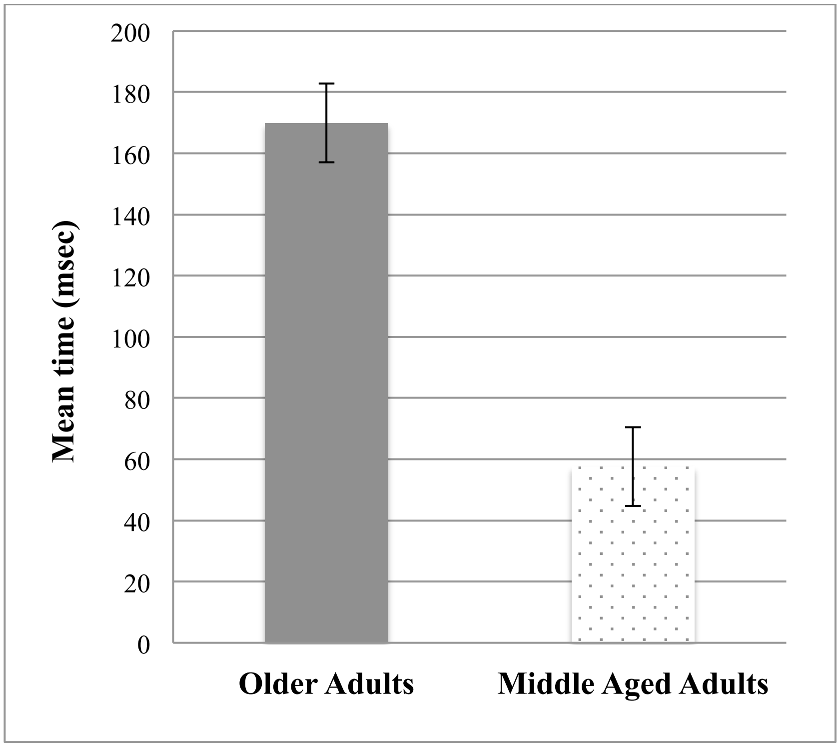


Figure 22. Main effect of age on UFOV selective visual attention. Error bars represent standard errors.

Appendices

Appendix A - Response Times (sec) for Correct Hazard Identifications

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	2.19 (.21)	1.91 (.20)	3.17 (.45)	2.65 (.32)
Manual	2.17 (.42)	2.05 (.14)	2.84 (.36)	2.19 (.26)

Note. Mean RTs are presented with standard deviations in parentheses.

Appendix B – Number of Correct Hazard Identifications

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	8.08 (.48)	12.33 (.48)	7.75 (.93)	8.92 (.50)
Manual	8.91 (.68)	11.91 (.62)	8.00 (.73)	10.83 (.65)

Note. Mean RTs are presented with standard deviations in parentheses.

Appendix C - Variability In Response Time (sec) for Precision of Correct Hazard Identifications

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	1.56 (.31)	.87 (.04)	1.86 (.35)	1.78 (.34)
Manual	1.24 (.28)	.86 (.10)	1.38 (.13)	1.19 (.18)

Note. Mean RTs are presented with standard deviations in parentheses.

Appendix D - Response Times for UFOV Processing Speed

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	15.33 (1.96)	15.08 (.30)	21.18 (2.05)	15.82 (.32)
Manual	15.18 (2.05)	15.09 (.32)	16.92 (1.96)	15.08 (.31)

Note. Mean RTs are presented with standard deviations in parentheses.

Appendix E - Response Times for UFOV Divided Attention

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	20.00 (16.30)	18.00 (7.02)	94.09 (17.03)	36.46 (7.33)
Manual	16.00 (17.03)	15.00 (7.33)	53.33 (16.30)	27.67 (7.02)

Note. Mean RTs are presented with standard deviations in parentheses.

Appendix F – Response Times for Selective Attention

	Middle Aged		Older Adults	
	Pre-test	Post-test	Pre-test	Post-test
Automatic	72.00 (21.89)	65.50 (16.82)	181.46 (22.86)	174.36 (17.57)
Manual	48.91 (22.86)	44.00 (17.57)	166.67 (21.89)	157.25 (16.82)

Note. Mean RTs are presented with standard deviations in parentheses.

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