A randomized trial of a comprehensive training process to enhance safe driving in older adults

by

Erica Sawula

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

In Canada, older adult driving exposure is increasing quite drastically. However, older adult drivers have a higher motor vehicle collision fatality risk compared to younger age groups. Therefore, older adult driver safety is an area requiring considerable attention. Using a randomized controlled trial study design, the present study investigated the effectiveness of a comprehensive training process to enhance safe driving in older adults. Based on their age and sex, participants (n=78), aged 65 years and above, were block randomized to one of three driving training intervention groups: 1) in-class training (control); 2) in-class plus on-road training (with individualized feedback); and 3) in-class plus on-road plus simulator training (with individualized feedback). The main outcome measure was the number of unsafe-driving actions committed before and after receiving designated driving training interventions on a standardized on-road driving evaluation, captured by video and GPS technology, and scored by a blinded, independent rater. Driving knowledge and driving comfort data were also collected for all participants before and after receiving their designated interventions. Mean baseline total on-road driving scores were similar for intervention groups, averaging 129.78 (SD=29.87) for the control group, 128.48 (SD=20.15) for the in-class plus on-road training group, and 127.73 (SD=24.24) for the in-class plus on-road plus simulator training group. The control group achieved an average reduction of 7.18 (95% CI [0.11, 14.26]) unsafe-driving actions; the in-class plus on-road training group and the in-class plus on-road plus simulator-training group achieved an average reduction of 41.64 (95% CI [26.21, 53.29]) and 38.69 (95% CI [22.20, 52.16]) unsafe-driving actions, respectively, especially regarding vehicle control and observation errors. Driving knowledge also significantly improved from 74.4% to 83.2% of questions answered correctly before receiving the in-class training component to after receiving the in-class training component; however, there were no significant differences between intervention groups in post-intervention driving comfort levels. The findings demonstrate that achieving considerable improvements in older adults' driving relies on on-road training, and that individualized feedback supplementation should be the focus of more inquiry. Limitations and future research directions are also discussed.

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Introduction

Background

In Canada, older adult drivers represent the fastest-growing segment of the driving population (Canadian Association of Occupational Therapists, 2009). For instance, the number of licensed drivers in Canada aged 65 years and above rose from 2,496,849 in 2000 (Transport Canada, 2001) to 3,760,035 in 2012 (Transport Canada, 2014), an increase of 50.6%. Additionally, the number of older adult drivers is expected to double by 2040 (Canadian Association of Occupational Therapists, 2009). Unfortunately, motor vehicle crashes are the leading cause of unintentional deaths for Canadians aged 65 to 74 years old (Canadian Association of Occupational Therapists, 2009; Public Health Agency of Canada, 2015). In fact, older adult drivers represented the highest number of traffic-related collision fatalities in any age group in 2012 (Transport Canada, 2014). Of particular concern, and part of the reason for their elevated risk of fatality, is that when older adult drivers are involved in crashes, they are often hurt more seriously than younger drivers due to frailty (i.e., the inability to recover from injury) (Eby & Molnar, 2012; Li, Braver, & Chen, 2003; Transport Canada, 2011). With the number of older adult drivers increasing, and their high fatality risk compared to younger age groups, the safety of older adult drivers is an area that requires considerable attention.

When older adult drivers are involved in motor vehicle crashes, the situations are generally different from those associated with crashes involving younger drivers. For instance, older adult drivers are more likely to be involved in intersection crashes than younger drivers (Hakamies-Blomqvist, 2004; Kay, Bundy, Clemson, & Jolly, 2008; Langford & Koppel, 2006; Li et al., 2003; Mayhew, Simpson, & Ferguson, 2006; McGwin & Brown, 1999; Pruesser, Williams, Ferguson, Ulmer, & Weinstein, 1998), especially when attempting to make left-hand turns at intersections (Abdel-Aty, Chen, & Schott, 1998; Abdel-Aty, Chien, & Radwan, 1999; Braitman, Kirley, Ferguson, & Chaudhary, 2007; Chandraratna & Stamatiadis, 2003; Mayhew et al., 2006; Staplin, Lococo, Martell, & Stutts, 2012). Crashes occurring while changing lanes are also more common among older adult drivers (McGwin & Brown, 1999; Staplin et al., 2012). Furthermore, the errors most often performed in older adult driver motor-vehicle collisions are failing to yield the right of way (Braitman et al., 2007; Finison & Dubrow, 2002; Mayhew et al., 2006; McGwin & Brown, 1999; Thompson, Baldock, Mathias, & Wundersitz, 2013) and failure to obey traffic signs (McGwin & Brown, 1999; Thompson et al., 2013).

The specific driving scenarios that are particularly challenging for older adult drivers may be attributed to normal age-related declines in specific functions related to driving abilities. For instance, age-related changes such as declining vision (Rubin et al., 2007), slower speed of processing (K. K. Ball et al., 2006; Rubin et al., 2007), cognitive impairments related to dementia (Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson, 1998), and declines in physical abilities (Marottoli, Cooney, Wagner, Douchette, & Tinetti, 1994; Marottoli et al., 1998) are related to motor vehicle crashes in older adult drivers. Health-related impairments, such as diabetes mellitus and cardiovascular disease, also play a role in older adult drivers' difficulties (Koepsell, Wolf, & McCloskey, 1994; McGwin, Sims, Pulley, & Roseman, 1999). In addition to age-related changes in functions related to driving skills, the lack of formal driving training for many older adult drivers may also contribute to their overrepresentation of certain crash-related situations and errors, as they may be unaware of driving rules and standard practices taught through driver-education training (Bédard et al., 2008).

Typically, there have been two approaches to declines in driving abilities and increased traffic-related collision fatalities in older adult drivers. The first is to identify unsafe drivers and restrict their driving privileges. However, the immediate solution to improving older adult driver safety should not be to limit or remove the driving privileges of older adult drivers, as driving restriction and cessation are associated with numerous, predominantly negative, effects such as decreased out-of-home activity (Johnson, 1999; Marottoli et al., 2000; Taylor & Tripodes, 2001), decreased social integration (Mezuk & Rebok, 2008), and increased depressive symptoms (Fonda, Wallace, & Herzog, 2001; Marottoli et al., 1997; Windsor, Anstey, Butterworth, Luszcz, & Andrews, 2007). The feelings of loss, isolation, and dependence associated with driving cessation can also affect well-being, health status, and quality of life (Oxley & Whelan, 2008). The negative consequences associated with driving reduction and cessation led a group of experts in older adult mobility to conclude that it is beneficial to society to keep older adults driving for as long as they can safely do so (Dickerson et al., 2007). Therefore, another common approach to declining driving abilities and increased traffic-related collision fatalities in older adult drivers, and what should be considered as the first line of intervention for the majority of drivers, is to optimize their driving behaviour.

Theory Underlying Safe Driving

To improve safe driving in older adults, it is possible to intervene on three different levels: 1) the driving environment, 2) the vehicle, and 3) the driver (Wang & Carr, 2004). Improving the driving environment may involve large-scale government-level changes in road design and management, such as improving the visibility of traffic signs or including more left-turn lanes (Brewer, Murillo, & Pate, 2014). However, if older adult drivers are uneducated regarding standard driving practices, improving the driving environment may not be entirely effective. Improving the vehicle to account for some of the deficits in abilities common in older adult drivers may involve enhancements at the vehicle design and engineering levels, such as night vision enhancement systems (Rumar, 2002). However, Eby and Molnar (2012) caution that without adequate knowledge about new vehicle features and technologies, the benefits of new vehicle designs may actually compromise safety thus additional training and education efforts will be required. Finally, improving the driver may include enhancing driver-assessment capacities to identify unsafe drivers, or providing driver-retraining courses. In a focus group study to determine the interest of older adult drivers in retraining courses, many indicated a desire to update their knowledge of the rules of the road because of the length of time that has passed, 50 years or more, since they had undergone any driving training (Kua, Korner-Bitensky, & Desrosiers, 2007). Improving the driver may have more immediate benefits for older adult drivers compared to improving the driving environment or improving the vehicle, not only in updating their knowledge regarding the rules of the road, but also in learning about how to adjust driving to allow for age-related changes that may impact driving safety. The driver level can be further separated into four potential intervention domains (Michon, 1979): 1) cognition, 2) physiology, 3) self-beliefs and personality, and 4) experience and knowledge.

Cognition. The cognition domain comprises several sub-domains including attention, visuospatial abilities, reaction time, and memory (De Raedt & Ponjaert-Kristoffersen, 2001; Marottoli et al., 1998; McKnight & McKnight, 1999). These aspects of cognition are related to driving outcomes such as crash risk and on-road driving performance (Anstey, Wood, Lord, & Walker, 2005).

Physiology. The physiology domain comprises sub-domains such as fitness, senses, health status, and medication use. As a person ages, physical changes such as psychomotor slowing, and decreased strength and joint flexibility may potentially impact driving ability (Tarawneh, McCoy, Bishu, & Ballard, 1993). Health-related limitations, especially those associated with the lower body and spine, also appear to produce driving difficulties in older adults (Tuokko, Rhodes, & Dean, 2007).

Self-beliefs and personality. The self-beliefs and personality domain includes several sub-domains such as driving skills, confidence, comfort, and driving need. Lower comforts with driving and poorer perceived driving abilities are related to actual driving behaviour (Blanchard & Myers, 2010; MacDonald, Myers, & Blanchard, 2008). In addition, certain aspects of personality, such as extraversion, may have a negative relation with driving performance (Adrian, Postal, Moessinger, Rascle, & Charles, 2011).

Experience and knowledge. The experience and knowledge domain is composed of sub-domains such as driver education, retraining, and experience. Driving experience and training can impact driving safety through increased knowledge about safe-driving practices, and improved driving skills, such as vehicle control (Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010). For example, on-road driving experience develops anticipatory abilities to avoid hazards and crashes further in advance (Lindstrom-Forneri et al., 2010).

Driver control levels. All domains and sub-domains associated with the driver are linked to three control levels proposed by Michon (1979): 1) the strategic level, which involves decisions regarding the driving plan, such as planning the driving route; 2) the tactical level, which includes decisions relevant to driving situation awareness, such as speed adjustment; and 3) the operational level, which comprises actual driving actions that may have an impact on crashes, such as braking and steering maneuvers. Problematic driving situations that are common to older adult drivers point to the need for driving interventions to focus on all three control levels of driving.

Effectiveness of Driver Training Programs

An increasing number of training programs are available for older adult drivers accompanied by a growing interest in their effectiveness. A previous systematic review of driving-related interventions specific to older adult drivers identified eight driving-specific intervention studies published up to 2004 (Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, 2007). For this systematic review, all randomized clinical trials, pre-post study designs, cohort studies, case-control studies, and descriptive studies were considered for inclusion if they focused on drivers aged 55 and older and on retraining of driving skills or skills necessary for driving (Kua et al., 2007). Articles on retraining of driving for those with neurological conditions were excluded. Kua and colleagues (2007) appraised RCTs for methodological quality (i.e., randomization, concealed allocation, baseline comparability, intention-to-treat analysis, etc.) using the Physiotherapy Evidence Database (PEDro) Scale (PEDro, 2006), while cohort and case-control were appraised using the framework provided by the Newcastle-Ottawa Scale (Wells et al., 2006).

In a more recent systematic review with the same inclusion and exclusion criteria, four more studies examining the effectiveness of older driver retraining were identified (Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009). Additional research has been conducted in more recent years to examine more targeted driving-related interventions for older adult drivers. In general, these programs comprise 1) physical training, 2) cognitive training, 3) education, and 4) education with individual training on-road or on a driving simulator.

Physical training. Physical training programs are of varying quality and provide only some evidence that physical retraining interventions improve driving performance in older adults (Korner-Bitensky et al., 2009; Kua et al., 2007). For instance, Ostrow and colleagues (1992) conducted a randomized control trial (RCT) of 38 older adult drivers, aged 60–85 years old, to investigate the impact of a range-of-motion training program on flexibility and driving skills. The intervention group completed 8 weeks of range-of-motion training (i.e., stretching exercises of the upper body), compared to the control group who did not receive the range-of-motion training (Ostrow et al., 1992). Outcome measures, conducted at pre-intervention and 8 and 11 weeks after receiving the training, included eight flexibility activities (e.g., trunk and neck rotation, side bends) and nine on-road actions (e.g., handling, straight-line backing, observing), observed by an examiner (Ostrow et al., 1992). Researchers found that the range-of-motion exercise training program successfully improved shoulder flexibility ($F(2,60)=3.23$, $p<.05$) and trunk rotation to the right ($F(2,60)=3.31$, $p<.05$), as well as in-car observing ($F(2,59)=3.62$, $p<.05$) at 11 weeks, in the experimental group compared to the control group, when examining the interaction of group and test session time (Ostrow et al., 1992). However, there were significant improvements in handling position ($F(2,59)=3.55$, $p<.05$) in the control group compared to the experimental group, when examining the interaction of group and test session time (Ostrow et al., 1992). Nevertheless, Kua and colleagues (2007) classified the RCT as “fair” in quality, since there was no mention of blinding the examiner to group allocation, and multiple comparisons were performed without statistical correction.

McCoy and colleagues (1993) conducted an RCT with 95 older adult drivers, aged 65–88, to investigate whether different types and combinations of interventions improved on-road driving performance. The researchers investigated a number of driving-related interventions, including physical therapy (i.e., at-home exercises designed to improve trunk rotation, neck and shoulder flexibility, and posture, to be done four times per week for eight weeks), perceptual therapy (i.e., at-home exercises designed to improve visual perception, to be done four times per week for eight weeks), driver education (i.e., one day, eight-hour classroom instruction), the combination of physical therapy and driver education, and the combination of perceptual therapy and driver education, all of which were compared to a control group that received no training (McCoy et al., 1993). An on-road driving outcome measure, performed at pre- and post-intervention, consisted of a standardized 19-km route designed to measure driving maneuvers associated with older adult driver accidents (McCoy et al., 1993). The researchers found that all intervention groups, with the exception of the perceptual therapy group, showed improvements in driving performance compared to the control group ($p < .015$). Comparisons between intervention groups did not significantly differ. The lack of significant findings in these areas may be attributed to the small sample size. Kua and colleagues (2007) again classified this RCT as only “fair” in quality, since the high number of intervention groups contributed to small sub-group sizes, and again there was no mention of blinding of evaluators.

Further, Marottoli and colleagues (2007) conducted an RCT consisting of 126 older adult drivers with physical impairments, aged 70 years and older, to examine whether a multi-component physical conditioning program could improve driving performance among older adults. The intervention group received a 12-week exercise program targeting flexibility, coordination, and speed of movement, which was led by a trained physical therapist; the control group received no such physical training (Marottoli et al., 2007). Outcome measures included change in driving knowledge on a road test with standardized scoring, and change in on-road driving performance as rated by a driving evaluator using standardized scoring criteria, both measured at baseline and three months post-intervention (Marottoli et al., 2007). The intervention group scored significantly higher in driving knowledge relative to baseline compared to the control group ($p<.001$), as well as significantly higher in on-road performance scores (i.e., 36% reduction in the number of driving errors) relative to baseline compared to the control group ($p=.001$). Korner-Bitensky and colleagues (2009) classified this RCT as “high” in quality, as it included blinding of the examiner to group allocation, and had standardized criteria for rating the road test.

Additionally, Marmeleira and colleagues (2009) conducted an RCT with 32 older adults, aged 60–81 years, to investigate the effects of participation in an exercise program on several abilities associated with driving performance in older adults. The intervention group attended a 12-week exercise program that targeted perceptive, cognitive, and physical abilities associated with driving performance, while the control group received no such training (Marmeleira et al., 2009). Outcome measures, conducted before and after the intervention, included measures of behavioural speed, visual attention, psychomotor performance, speed perception, and executive functioning (Marmeleira et al., 2009). Researchers found significantly greater improvements in reaction time (dual task: -13%, p=.018), movement time (single task: -15%%, p=.026), response time (single task: -10%, p=.035; dual task: -13%, p=.018), and speed of processing (-66%; p=.032) when comparing the intervention group to the control group (Marmeleira et al., 2009). However, this RCT utilized a relatively small sample size, and did not include an actual on-road driving performance outcome measure, only measures that have been related to driving.

Finally, Chattha (2010) conducted an RCT including 29 older adults, aged 55 years and above, to determine the effects of a fitness intervention on driving performance and relative cognitive abilities. The fitness intervention comprised a 12-week combined aerobic (cardiovascular) and anaerobic (strength, flexibility) training program; the wait-list control group received no such training (Chattha, 2010). Outcome measures, collected pre- and post-intervention, included cognitive, driving performance on a driving simulator, and physical functioning data (Chattha, 2010). A significant intervention effect was found for some cognitive abilities relevant to driving, including general visual attention ($F(1,21)=5.695$, p=.027) and selective attention ($F(1,20)=14.14$, p=.001). However, only the control group made significantly fewer total driving errors after 12 weeks only on the rural highway driving scenario ($F(1,11)=14.207$, p=.003; Chattha, 2010). It is important to note that this RCT had a limited sample size, and thus, the lack of significant findings for driving performance outcomes may be attributed to this.

Also, the study did not include an actual on-road driving performance outcome measures, only simulated driving performance and measures that have been related to driving.

As Korner-Bitensky and colleagues (2009) highlight, there is only moderate evidence from one high-quality RCT and one fair-quality RCT that physical retraining interventions improve driving knowledge in older adults, and only moderate evidence from one high-quality RCT and two fair-quality RCTs that physical training interventions improve on-road driving performance in older adults. The weaknesses of these and more recent RCTs namely include sample size limitations, the lack of concealed allocation, and/or standardized outcome measures specific to on-road driving performance. Consideration of these limitations is necessary in order to conduct a "high" quality intervention. Further, due to the lack of strong evidence that physical retraining interventions improve on-road driving performance, retraining interventions should focus on areas that have shown greater success for this outcome, as well as ensure stricter methodological considerations.

Cognitive training. There are few training interventions for older adult drivers that have focused on cognitive abilities relevant to driving. For instance, Roenker and colleagues (2003) conducted an RCT of 104 older adult drivers, mean age of 71 years, to evaluate the effects of speed-of-processing training versus simulator training on older adults' psychomotor and driving performance. Participants were randomized to one of three intervention groups, including a speed-of-processing training program (4.5 hours in one day), a traditional driver training program performed in a driving simulator (4 hours across 2 days), or a control group (Roenker et al., 2003). Outcome measures, collected at pre-training, post-training, and after 18 months, included a measure of useful field of view (UFOV®), a driving evaluation on a driving simulator, and an on-road driving evaluation on a 7-mile route (Roenker et al., 2003). Researchers found that the speed-of-processing group had significantly better UFOV scores compared to the simulator-training group at post-test ($F(2,92)=19.32$, $p<.001$), and a significant decrease in dangerous maneuvers during driving ($F(4, 184)=2.89$, $p<.024$) in the speed-of-processing training group compared to the simulator-training group (Roenker et al., 2003). However, of three raters used to evaluate study participants, only one was blind to group allocation, garnering only a "fair" quality RCT rating (Kua et al., 2007). Further, on-road driving performance was scored based on a global rating averaged across two raters who rated on a 1–6 scale in which 1=aborted drive and 6=competent driver (Roenker et al., 2003). Categorization of drivers, as opposed to totalling the number of driving errors observed, may not give an accurate representation of change in on-road driving performance.

Additionally, Ball and colleagues (2010) conducted an RCT of 908 drivers, aged 65 and above, to compare the effect of cognitive training on motor vehicle collision involvement in older adult drivers. Participants were randomized to one of three cognitive training interventions (up to 10 sessions of memory, reasoning, or speed-of-processing training) or a control condition (Ball et al., 2010). State-reported motor vehicle collisions were obtained from the Department of Motor Vehicles, and only included collisions that occurred after study enrollment (Ball et al., 2010). Researchers found that training in cognitive speed-of-processing and reasoning resulted in approximately 50% lower at-fault motor vehicle crashes in older adult drivers (speed of processing: RR=0.57, CI=0.34-0.96; reasoning: RR=0.50, CI=0.27-0.92) compared to the control group (Ball et al., 2010). The researchers concluded that cognitive training may improve driving skills and reduce crash rates (Ball et al., 2010). However, the latter has been disputed by Bédard and Weaver (2011). For example, while cognitive training conducted by Ball and colleagues (2010) resulted in lower at-fault crash risks, their findings suggest increased not-at-fault crash risk in participants belonging to the successful intervention groups (Bédard & Weaver, 2011). Further, motor vehicle collision involvement may not be an accurate measure of driving performance, as only the most extreme cases of poor driving performance would be collected. In addition, collisions are often a result of multiple contributing factors. As such, it is difficult to attribute poor driving performance to an increased number of motor vehicle collisions without further investigating crash responsibility.

While positive conclusions were drawn in both studies regarding cognitive training and its effect on driving performance, there are limitations in both investigations, including outcome measure accuracy, that yield caution in concluding that cognitive training interventions improve driving-related skills in older adult drivers. Further, due to the limited amount of consistent research conducted in this area, again, it may be of greater benefit to focus retraining interventions on areas that have shown greater success for this outcome.

Education programs. The majority of education programs for older adult drivers include some form of classroom training. Owsley and colleagues (2003) performed an RCT of 365 visually impaired individuals, aged 60 years and above, to evaluate the efficacy of an educational intervention aimed at changing self-perceptions about vision impairment to avoid challenging driving situations. Drivers were randomized to either an experimental group who received two sessions of education to promote safe driving and a comprehensive eye examination, or a control group who received only the eye examination (Owsley et al., 2003). Outcome measures were collected before randomization and six months post-intervention, and included measures of self-rated eyesight, attitudes toward driving safety, and avoidance of challenging driving situations (Owsley et al., 2003). Researchers discovered that drivers who received the intervention were more likely to acknowledge they had less excellent eyesight ($t(1,349)=2.26$, $p=.02$), report a higher frequency of avoiding challenging driving situations ($t(1, 360)=6.21$, $p<.01$), and performed more self-regulatory practices ($t(1, 350)=8.24$, $p<.01$), such as waiting until a rain shower stops before driving, compared to the control group (Owsley et al., 2003). Kua and colleagues (2007) classified this RCT as “strong” in quality due to the strength of its internal validity. However, it is important to note that the outcome measures used are not of on-road driving performance, but rather measures of factors that may influence safe driving.

Similarly, Owsley and colleagues (2004) conducted another RCT of 403 older adults with visual impairment, aged 60 years and above, to investigate the impact of an educational training program on safe-driving strategies. Participants were again assigned to either an experimental group who received educational training to promote safe driving and a comprehensive eye examination, or a control group who only received the comprehensive eye examination (Owsley et al., 2004). This time, outcome measures were administered at baseline and every six months after training for two years, and included self-reported driving habits and crash involvement as obtained from accident reports (Owsley et al., 2004). Researchers found increased self-regulation and avoidance of challenging driving situations and decreased driving exposure ($p<.001$; Owsley et al., 2004) in the experimental group compared to the control group. However, the intervention group did not differ significantly from the control group in crash rate per 100 person-years of driving (RR= 1.08; 95% CI= 0.71-1.64; Owsley et al., 2004). Again, this RCT garnered a classification of "high" quality due to its strong internal validity (Kua et al., 2007). However, the authors also recognize that the sample size is quite small to identify differences in crash rates (Kua et al. 2007). Further, and as previously mentioned, crash rates may not be an accurate representation of driving performance.

In terms of actual on-road driving performance, driver classroom education programs have not shown consistency in this outcome. For example, Bédard and colleagues (2004) conducted an RCT of 65 participants, aged 55 to 86 years, to evaluate the effectiveness of a driver re-training program on driving performance. Participants were randomized to either the intervention group (two half-day sessions of the 55 Alive/Mature Driving program developed by the American Association of Retired Persons and adapted by the Canada Safety Council) or control group, who received no such training until after completing follow-up evaluations (Bédard et al. 2004). Outcome measures, collected at baseline and post-intervention, included scores on a 35-minute on-road driving assessment performed on a standardized driving circuit (Bédard et al. 2004). The researchers found an overall improvement in on-road driving evaluation scores (3.73, SD=6.87, p=.001) after program attendance, but this improvement was similar for the training and control groups (t(63)=0.32, p=.75) (Bédard et al., 2004). This RCT was classified as "high" quality, due to its strong internal validity (Kua et al. 2007). Although the educational intervention was not associated with improved on-road performance in intervention participants compared to control participants, the researchers highlight that the on-road driving evaluation measure may not have captured the increase in awareness of safety issues among the training group (Bédard et al., 2004).

In a different study, Nasvadi and Vavrik (2007) used a matched-pairs cohort study design of 884 drivers, aged 55 years and above, to examine whether a driver re-training program reduced motor vehicle crash involvement. The intervention group attended the 55 Alive/Mature Driving program, and were matched with a control group of drivers who had similar crash rates to the intervention (Nasvadi &Vavrik, 2007). Outcome measures included automobile crash involvement obtained from the Insurance Corporation of British Columbia (Nasvadi & Vavrik, 2007). Researchers found that attendance in the re-training program was associated with higher post-course crash involvement for men aged 75 years and older (n=46) compared to controls within the same age group (n=31; OR=3.80, p=.05), but had no effect on subsequent crashes for younger men (subjects: n=28; controls: n=34) (Nasvadi & Vavrik, 2007). Therefore, the authors suggest that driver education programs may be successful in mitigating an increase in crashes for younger mature drivers but not the oldest of male drivers (Nasvadi &Vavrik, 2007). However, it should again be noted that the outcome measure of motor vehicle collision involvement may not provide an accurate representation of driving performance.

As Korner-Bitensky and colleagues (2009) suggest, there is 1) strong evidence that an educational intervention curriculum versus no intervention improves driving awareness; 2) strong evidence that an educational intervention curriculum versus no intervention improves driving behaviour; and 3) moderate evidence that an educational intervention curriculum versus no intervention is not effective in reducing crash rates. However, there are numerous variations in the definition of safe driving as well as outcome measures used across these studies (Korner-Bitensky et al. 2009). As such, it is difficult to conclude the actual impact that education training has on on-road driving performance. Although, due to the conclusions reached in numerous “high” quality investigations (i.e., Bédard et al. 2004; Nasvadi & Vavrik 2007), it is fair to suggest that education training should be supplemented with further instruction in order to improve on-road driving performance.

Education with individual training. In more recent years, individual training has supplemented driver education programs, with one-on-one training either in a car or driving-simulator environment. For instance, Marottoli and colleagues (2007b) conducted an RCT of 126 older adults, aged 70 years and above, to investigate whether a program consisting of an educational intervention and on-road training could enhance driving performance. Individuals randomized to the intervention group attended two class instruction sessions (four hours each, based on the American Automobile Association (AAA) Driver Improvement program) and two on-road training sessions (one hour each, focused on common problem areas of older adult drivers), while the control group received education modules directed at vehicle, home, and environmental safety presented by a research assistant (Marottoli et al., 2007b). Outcome measures, collected at baseline and at eight-week follow-up, included a driving knowledge test and a road test with standardized criteria for rating (Marottoli et al., 2007b). Researchers discovered that the least squares mean change in road test scores relative to baseline was 2.78 points higher in the intervention group than the control group (p=.001), and 3.45 points higher in knowledge test scores in the intervention group than in the control group (p<.001; Marottoli et al., 2007b). As such, the authors concluded that a program combining in-class education and an on-road refresher component can enhance driving performance (Marottoli et al., 2007b). Korner-Bitensky and colleagues (2009) classified this RCT as "high" quality. Specifically, their estimate of actual on-road driving performance was consistent, as the primary outcome measure had standardized scoring criteria, improving inter-rater reliability. As well, on-road assessors were blinded to participant group allocation, which minimizes observer bias and maximizes the validity of the results.

Similarly, Bédard and colleagues (2008) conducted an RCT of 75 older adults, aged 65 years and above, to examine if the combination of an in-class education program with on-road education would lead to improvements in knowledge of safe-driving practices and on-road driving performance. Participants were randomized to either an intervention group, who received two in-class education sessions (four hours each, based on the 55 Alive/Mature Driving Program) and two on-road driving lessons (30–40 minutes each, focused on concepts discussed during in-class training), or a control group who received no such treatment (Bédard 2008). Outcome measures, collected at baseline and after treatment, included a driving knowledge evaluation and an on-road driving evaluation conducted by a certified driving instructor (Bédard 2008). The intervention group's knowledge increased from 61% of questions correctly answered at baseline to 81% after the in-class component ($p<.001$). Improvements for the intervention group on some sections of the road test were statistically significant (e.g., moving in the roadway [$p=.049$]), but not others (e.g., passing/speed [$p=.183$], turning [$p=.643$]) (Bédard et al., 2008) compared to the control group. Again, Korner-Bitensky and colleagues (2009) classified this RCT as "high" quality, due to strong internal validity. Specifically, having only one blinded evaluator at each study site, and a standardized driving route, ensures greater consistency in on-road driving evaluation ratings.

Romoser and Fisher (2009) performed an RCT of 54 older adults, aged 70 to 89 years, to compare the effectiveness of simulator training and classroom training on older drivers' performance at intersections. Participants were randomized into one of three groups: 1) active simulator-training group, who received customized feedback from a replay of the participants' simulator and on-road drives; 2) passive classroom training group, who attended 60 minutes of traditional lecture-style training on older driver issues and scanning in intersections; or a control group who received no such training (Romoser and Fisher 2009). Primary outcome measures, collected at baseline and approximately six to ten weeks after completing training, included a simulator evaluation drive of three driving scenarios, as well as an on-road driving evaluation beginning at the participant's home on a route selected by the participant (Romoser & Fisher, 2009). Scanning movements were recorded using a four-camera system to capture head movements and the environment (Romoser & Fisher, 2009). There were significant differences between active and passive groups ($F(1,22)=13.11$, $p<.005$), and between active and control groups ($F(1,22)=11.83$, $p<.005$), but not between the passive and control groups, for scanning at intersections during the on-road driving evaluation (Romoser & Fisher, 2009). However, because the on-road driving evaluation route was chosen by the driver, the number and type of driving maneuvers performed were not consistent between participants. The use of the four-camera system is beneficial in providing an objective and more reliable measure of intersection scanning, but the use of a standardized on-road driving evaluation route would have allowed for more accurate comparisons between study participants' on-road driving performance.

More recently, Lavalliere and colleagues (2012) conducted a small RCT of 22 older drivers, aged 65 to 85 years, to evaluate if simulator training, coupled with video-based feedback, can modify visual search behaviours of older adult drivers while changing lanes. Participants were randomized to either a feedback group, who received a driving refresher course and feedback about their driving performance on a driving simulator, or a control group who also attended a driving refresher course and drove the same simulator scenario as the feedback group, but did not receive feedback about their driving performance (Lavalliere et al., 2012). The outcome measure, collected at pre-training and post-training, included a standardized on-road driving evaluation (Lavalliere et al., 2012). Researchers discovered that the feedback group drastically increased the frequency of blind spot checks before changing lanes (from 32.3% to 64.9%) compared to the control group ($F(1,19)=9.41$, $p<.01$) (Lavalliere et al., 2012). Although this study had a relatively small sample size, by providing the same active simulator practice session to the control group, researchers were able to determine that it was the individualized feedback that led to the improvement in performance of the active training group (Lavalliere et al., 2012).

Similarly, Porter (2013) conducted an RCT of 54 older adult drivers, aged 70 to 89 years, to determine if video and global positioning system (GPS) feedback of on-road driving performance, in addition to classroom education, would improve on-road driving performance. Participants were randomized to one of three groups: 1) video group, who attended the 55 Alive/Mature Driving program and received video and GPS feedback of their on-road driving performance; 2) education group, who attended only the 55 Alive/Mature Driving program; and 3) control group, who received no such training (Porter 2013). The outcome measure, collected at pre- and post-intervention, included an on-road driving test on a standardized route, which was recorded with video and GPS equipment (Porter 2013). The video group significantly reduced their driving errors by 25% ($p<.05$) following the intervention, while the other two groups did not. This research demonstrated strong internal validity, including its RCT design and ability to blind the outcome assessor, not only to group allocation, but to whether the test was pre- or post-intervention through the use of video technology (Porter, 2013). Video and GPS technology also allowed for more accurate capturing of on-road driving performance, as there is less risk of an in-car evaluator missing an action in real time.

Given the knowledge obtained from evidence in their systematic review, Korner-Bitensky and colleagues (2009) recommend that a driving retraining program for older adults include an educational intervention combined with an on-road component to increase general driving knowledge and driving-specific skills. Additionally, it is apparent that some form of individualized feedback, from either a simulator or on-road driving evaluation, may also increase on-road driving performance (Lavalliere et al., 2012; Porter, 2013; Romoser & Fisher, 2009). As such, in-class driving education, supplemented with either on-road or simulator training with individualized feedback, should be the focus of more inquiry. There is currently no evidence examining both forms of training simultaneously. Therefore, it remains unclear as to whether these forms of active training with feedback would yield greater improvements in on-road driving performance if combined.

Driving Confidence

Driving confidence is considered a key determinant in driving frequency and avoidance of certain driving situations in older adult drivers (Baldock, Mathias, McLean, & Berndt, 2006; Blanchard & Myers, 2010; Charlton et al., 2006; Marottoli & Richardson, 1998; Molnar & Eby, 2008). For instance, Myers and colleagues (2008) measured driving confidence in older adult drivers, aged 66 to 92 years, using the day (DCS-D) and night (DCS-N) driving comfort scales. Confidence scores were inversely associated with situational avoidance (day: $r = -.56$, $p<.001$; night: $r = -.49$, $p<.001$), and positively associated with self-reported driving frequency (day: $r = .55$, $p<.001$; night: $r = .53$, $p<.001$) and perceived abilities (day: $r = .34$, $p<.001$; night: $r = .43$; $p<.001$) (Myers et al., 2008). Donorfio and colleagues (2008) found that confidence in driving abilities declined with age. They also found an increase in self-regulation with declining confidence (Donorfio et al., 2008). Self-regulation may consist of reduced exposure, modification of driving patterns, avoidance of complex driving situations, or driving cessation (Blanchard & Myers, 2010). However, confidence in driving ability actually bears little relationship to on-road performance (Marottoli & Richardson, 1998; Riendeau, Maxwell, Patterson, Porter, & Bédard, 2014). As such, highly confident older adult drivers with actual abilities that do not match their perceptions may pose a heightened risk to themselves and others, and drivers with low confidence may cease driving prematurely (Paradis, 2006).

There is a paucity of research that has examined the impact of driver training interventions on driving confidence. Ultimately, it will be important to investigate interventions to decrease the mismatch between actual and perceived driving ability. First, it is necessary to explore whether driving training interventions targeted to improving driving performance have an effect on driving confidence.

Objective

A comprehensive driving training program was developed by experts in the field of older driver training, knowledge users (e.g., driver training providers), and consumers (older adult drivers). It is based on successful, evidence-based components of past driving training interventions for older adult drivers. The driving training program comprises several training components: 1) in-class education training; 2) on-road training with a review of on-road driving evaluation videos and individualized feedback of on-road driving performance; and 3) training on a driving simulator with individualized feedback of driving-simulator performance.

Three combinations of these training components will be evaluated, including: 1) the in-class education component only; 2) the in-class plus on-road training components combined; and 3) the in-class plus on-road plus simulator training components combined. The primary objective of this study is to examine the effectiveness of the driving training component combinations, in order to determine which components are necessary in enhancing safe driving performance in older adult drivers. The impact of driver training on self-reported driving comfort levels and driving knowledge is also investigated.

Primary hypothesis. It is hypothesized that participants receiving the in-class education component augmented with the on-road training component (including individualized on-road driving performance feedback) will perform fewer unsafe-driving actions after training than participants receiving only the in-class education component. Additionally, participants receiving the in-class education component augmented with the on-road training component and the simulator-training component (including individualized on-road driving and simulator-performance feedback) will perform fewer unsafe-driving actions after training than participants in the other two intervention groups.

The primary hypothesis is based on evidence from previous research; that is, refreshed knowledge on the rules of the road and safe-driving practices, increased awareness of unsafe-driving actions through the review of on-road driving evaluation videos with a driving instructor, increased awareness of unsafe-driving actions through feedback from a driving instructor, and reinforcement of concepts learned through driving simulation will lead to increased safe-driving behaviours.

Secondary hypotheses. It is also hypothesized that all participants will possess greater driving knowledge after completion of the in-class training component. This assumption is based on the premise that because all participants will receive in-class education on the rules of the road and safe-driving practices, all participants' driving knowledge will be improved.

Further, it is hypothesized that driving confidence, as conceptualized by comfort in various driving situations, will remain equal between intervention groups before and after receiving designated training. This assumption is based on the premise that because the driving training components are targeted towards safe-driving performance, they will not affect driving confidence.

Methodology

Study Design

We used a randomized control trial (RCT) study design. Based on their age and sex, participants were randomized to one of three driver training intervention groups: 1) Basic training (BT) group: received an in-class driving education component only; 2) On-road training (BT+OR) group: received both in-class education and on-road training components; 3) On-road and simulator-training (BT+OR+S) group: received in-class education, on-road, and simulator-training components. Before and after completing their designated training, participants also completed assessment questionnaires and an on-road driving evaluation. There were approximately 4–8 weeks between pre- and post-assessments. A research assistant (RA) at the University of Manitoba was responsible for analyzing and scoring the on-road driving evaluations to allow the study to adhere to a single-blind design; that is, the RA that scored driving outcomes was blinded to group allocation, as was the data analyst; participants knew which group they were assigned to by default.

Participants

Participants in Thunder Bay were recruited through newspaper ads, and television and radio interviews during which contact information for the study was included. Posters and presentations to various seniors' associations (e.g., 55 Plus Centre and Chartwell Thunder Bay Retirement Residence) were also used to identify volunteers for the study.

Inclusion and Exclusion Criteria

For inclusion, participants had to meet four criteria: (1) must be aged 65 years and over; (2) must possess a valid general-class driver's license; (3) must drive at least three times per week, because regular drivers are required for the primary outcome of safe-driving performance; and (4) must be able to speak and read fluent English, as assessment tools and questionnaires, as well as program instructions, were presented in English. The main exclusion criterion was evidence of dementia, as determined by a score of less than 24 on the standardized Mini-Mental Status Examination (see Appendix A; Molloy, Alemayehu, & Roberts, 1991).

Ethics

Ethics approval was obtained from Lakehead University. Informed consent to participate and consent to have an in-vehicle recording device installed in the participant's vehicle was obtained at the baseline assessment before any measures were administered.

Outcome Measures

Primary outcome measure. An on-road driving evaluation was used to assess participants' on-road driving performance before and after receiving their designated driving training. On-road driving performance data were collected using a custom-designed in-vehicle recording device (OttoView-CD autonomous data-logging device; Porter & Whitton, 2002) and video technology (Carcam III X8000 Twin Cam HD Car Camcorder with G Sensor and 360-degree rotating lens). The in-vehicle recording device has the following features: 1) it is powered by the participant's vehicle through the on-board diagnostic system; 2) it collects information from the vehicle including time/date of trip, speed, and acceleration; 3) it has a GPS antenna mounted on the dash and a receiver in the main device box so vehicle location information can be collected; and 4) an SD memory card is used to store the participant's data at a rate of 1 Hz per second. The video technology was used to visually capture participants' on-road driving performance. Two cameras, each equipped with dual rotating lenses, were placed in the interior of the car, as seen in Figure 1. One camera was mounted in the centre of the anterior windshield (blue dot), and captured the driver, the front field of view, and the rear view (purple lines). A second camera (green dot) was mounted in the centre of the passenger window, and captured the driver oncoming cars to the drivers' right, and oncoming cars to the drivers left (red lines). In the past, the video technology discovered different types of driving errors such as failure to stop at a stop sign and turning errors in older adult drivers (Porter & Whitton, 2002). A more recent study also utilized video and GPS scores to evaluate the effectiveness of older driver education (Porter, 2013).

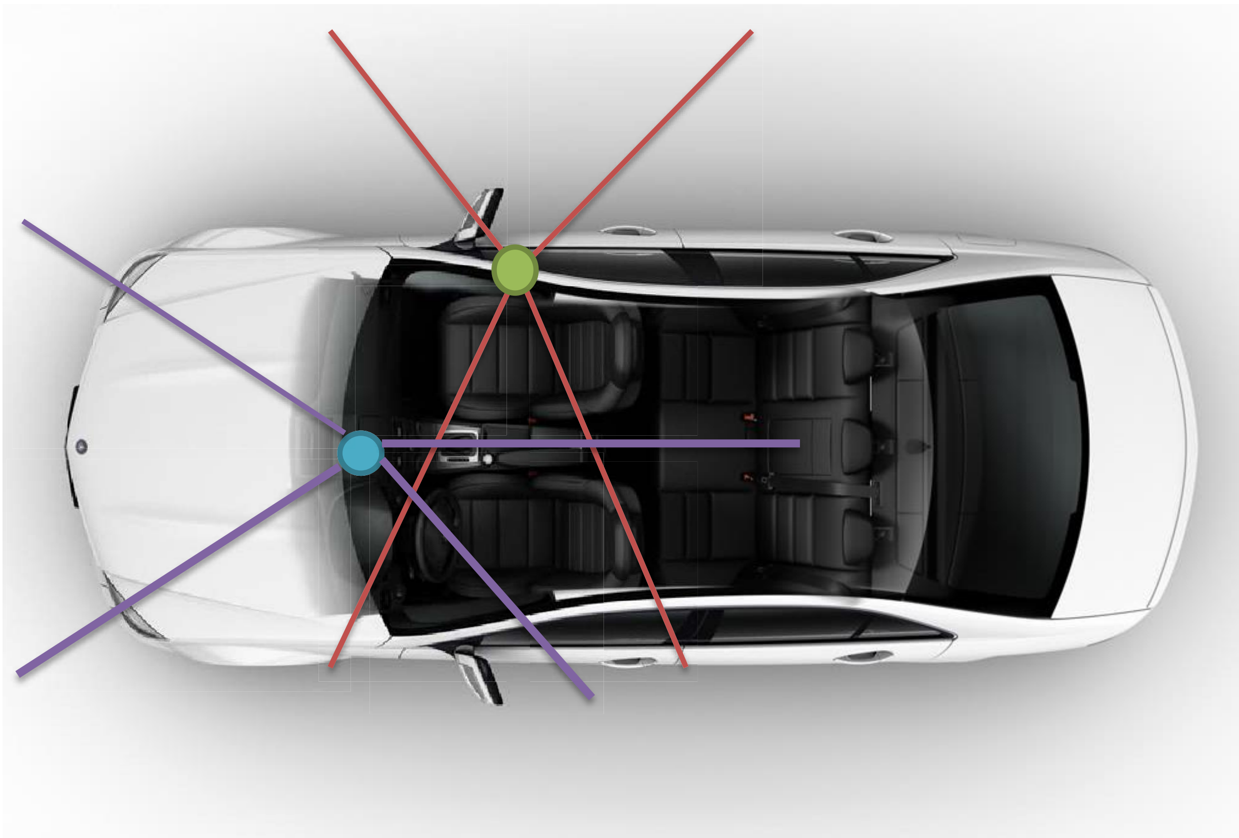

Figure 1. Video technology placement.

The on-road driving evaluations lasted approximately 30 minutes and consisted of a set of maneuvers mimicking the G2 Exit Road Test, which assesses advanced knowledge and skills that are generally gained through driving experience (e.g., ability to make turns, change lanes, use signals, and drive through intersections), and allows for full driving privileges upon successful completion. Evaluated maneuvers included left turns, protected/non-protected turns, and local versus highway driving (see Appendix B). All evaluations were conducted during daylight, non-rush hours (between 9 am and 4 pm), and in adequate weather conditions (sunny or light rain). An RA accompanied each participant for the on-road driving evaluation to provide general instructions and orientations to the driver. The RA sat in the passenger seat and provided, ahead of time, verbal instructions about upcoming maneuvers. This ensured the evaluation route was standardized for all participants. No feedback on driving performance was provided during the evaluation.

An RA at the University of Manitoba scored video output using a scoring method utilized reliably in the past (Porter, 2013).That is, the RA assessed the drivers' performance by scoring one point for each unsafe-driving action where the driver; that is, when the driver did not demonstrate safe-driving practices (e.g., follows too closely, fails to check blind spot during lane change). As such, a higher on-road driving score indicated a higher number of unsafe-driving actions. The RA was blinded to the identity of the participants, their training group allocation, and whether it was a pre- or post-intervention evaluation. Before beginning the official scoring of the videos, the evaluator practised with non-participant videos to finalize the scoring system. Checks were performed throughout the scoring process by scoring a small set of randomly selected videos a second time and comparing these scores with the original scores. This ensured reliability of the RA. Each maneuver (e.g., left-hand turn at intersection) in the on-road driving evaluation was examined for four categories of safe-driving practices, including: 1) vehicle controls; 2) procedural; 3) observations; and 4) compliance errors (see Appendix C).

Vehicle controls consisted of: a) signalling (e.g., too early, not given, not cancelled); b) hand position on the steering wheel (e.g., too low, too high, one hand); c) deceleration (e.g., harsh, pumping); d) acceleration (e.g., harsh, too quickly); and e) other (e.g., wipers, hazard lights, gears). Procedural errors involved: a) position in lane (e.g., left, right, wanders, straddles lane); b) stop position (e.g., over line, blocks crosswalk, too early); c) flow (e.g., impedes traffic, too fast, too slow); d) drives in wrong lane (e.g., doesn't move to right late after executed a turn); e) position on approach (e.g., too far from curb/centre); f) response to traffic lights (e.g., amber); g) left at light (e.g., wait position, wheels straight); h) right on red (e.g., complete stop). Observations consisted of: a) mirrors (e.g., while driving, while slowing, while stopped); b) blind spot checks (e.g., during lane changes); c) intersection scans (e.g., all streets, at lights); d) blind spot checks (e.g., turning right, turning left); e) look in direction of movement. Finally, compliance errors involved: a) stops (e.g., incomplete); b) impedes traffic (e.g., lane changes, merging, too slow); c) fails to yield (e.g., pedestrians, bikes, ambulance, traffic); d) fails to clear intersection; e) right-of-way (e.g., car, pedestrian, bike); f) speeding (e.g., school zone, 5 km/h or more over speed limit); g) follows too closely; h) turns (e.g., into wrong lane); i) stops without cause; j) drives on wrong side of road; k) passing too close (e.g., dangerous, speed); l) hits curb, hits anything. One point was assigned for each observed unsafe-driving action executed per maneuver.

In addition, drivers' data from the in-vehicle recording device were used to score for speed-related infractions (e.g., whether drivers came to a complete stop at stop signs, speeding). These data constituted extra unsafe-driving action points and were combined with unsafe-driving action points from the video output to establish a final score for each driver's performance. For the selected route, the total possible number of unsafe-driving actions to be scored was 1440 (i.e., if scored 1 point for each unsafe-driver action (30) for each maneuver (48)). For vehicle controls, the total possible sub-score was 240 (i.e., if scored 1 point for each vehicle control error (5) for each maneuver (48)). For procedural errors, the total possible sub-score was 384 (i.e., if scored 1 point for each procedural error (8) for each maneuver (48)). For observations, the total possible sub-score was 240 (i.e., if scored 1 point for each observation error (5) for each maneuver (48)). Finally, the total possible sub-score for compliance errors was 576 (i.e., if scored 1 point for each compliance error (12) for each maneuver (48)).

The total number of unsafe-driving actions was used as the main outcome variable of this study. In the past, the video technology discovered different types of driving errors such as failure to stop at a stop sign and turning errors in older adult drivers (Porter & Whitton, 2002). A more recent study also utilized video and GPS scores to evaluate the effectiveness of older driver education (Porter, 2013).

Secondary outcome measures. Secondary outcome measures included knowledge about safe-driving practices and driving comfort levels. Driving knowledge and driving comfort levels were collected from participants using paper-and-pencil questionnaires.

Driving knowledge evaluation questionnaire. Based on content from the in-class training component, this questionnaire consists of eight multiple-choice questions about the rules of the road (see Appendix D). For example, one question states, "You are approaching a signal when the light suddenly changes from green to yellow. You should: a) Sound your horn to indicate you are going through; b) Accelerate and clear the intersection as quickly as possible; c) Stop. If a stop cannot be made safely, proceed with caution; d) Switch into the left-most lane." Participants were only given one full point if they answered "c." Hence, the total score ranged from 0–8, with higher scores indicating better knowledge. The same eight questions were presented before and after the in-class training component. Correct answers were only provided once the post-training questionnaire was complete.

Driving comfort scales. Developed by Myers and colleagues (2008), this questionnaire includes 13-item day (DCS-D) and 16-item night (DCS-N) driving comfort scales (see Appendix E). For example, one question asks, "How comfortable are you driving in the daytime…in light rain?" Participants were asked to rate their level of comfort by choosing one option from the following scale: 0% (not at all comfortable), 25%, 50% (moderately comfortable), 75%, or 100% (completely comfortable). Participants were asked to consider confidence in their own driving abilities, as well as the situation itself. Higher scores indicate higher levels of comfort. The DCS-D and DCS-N were shown to be internally consistent (α= .92 and .97) with good test-retest reliability (ICCs= .70 and .88; Myers et al., 2008).

Training Interventions

In-class education component. The in-class education component was a group-based refresher course for older drivers, designed specifically to help improve their safe-driving behaviours. The course was developed by Admiral Training and the Centre for Research on Safe Driving at Lakehead University. The goal of this component was to maximize the safe-driving behaviours of older adult drivers, and produce law-abiding, proficient, and aware drivers who are able to drive safely and pass testing administered by the province. The course focused on areas that are typically of concern for older adult drivers. For instance, participants learned about the benefits of being able to drive, factors affecting driving as an older adult (i.e., vision impairment), traffic control devices, and intersections. It further helped to improve awareness of traffic hazards, and identify and correct any bad driving habits. A qualified instructor who was well versed in driving and aging instructed the course in one 3-hour session. The course was established to be 3 hours, as it was determined in our consensus process with older adults to be the longest acceptable course length for older adults.

On-road training component. To reinforce the concepts discussed in the classroom setting, participants randomized to either the BT+OR or BT+OR+S groups participated in an on-road training component with a certified driving instructor that comprised two elements: 1) a review of their pre-assessment driving video in which the instructor provided the participants with constructive feedback on their driving behaviour; and 2) two 45-minute, on-road practice sessions with the instructor to reinforce changes suggested after viewing the videos. Specifically, the on-road training component focused on areas of concern that need to be emphasized with senior drivers, including blind spot checks, mirror use, highway on/off ramps, spotting hazards, right-of-way and intersection procedures, stops and stop positions, and bike lanes.

Simulator-training component. To further reinforce the concepts discussed during the in-class and on-road training components, participants randomized to the BT+OR+S group also participated in one 45-minute simulator practice session after completion of the on-road training component. Specifically, the simulator practice session featured a simulated version of the G2 Exit Road Test. Prior to completing the simulated road test, participants received a ten-minute simulator-training session to familiarize themselves with the simulator. Participants then completed the simulated road test, during which they were provided with standardized feedback for areas of improvement from an RA (see Appendix F). Participants completed the simulated road test a second time, while receiving no feedback, to improve upon errors they made during the first simulated road test.

Procedure

An RA contacted interested participants by phone to describe the study in more detail. The RA and participant then met in person to conduct a screening interview. At the beginning of the interview, participants were given an information letter describing the study, including confidentiality of the data and the right to withdraw at any time without penalty. A signed consent form was then obtained from the participant. The screening interview took approximately 15 minutes to complete and consisted of the SMMSE and demographic information (see Appendix G). If a participant met all inclusion criteria, they completed all pre-assessment questionnaires, including: 1) a Driving History/Habits questionnaire (see Appendix H); 2) the Driving Comfort Scales; 3) a Driving History Profile (see Appendix I); 4) a Driving Knowledge Evaluation; and 5) an on-road driving evaluation. The pre-assessment interview took approximately 45 minutes to complete.

Once enough participants completed pre-assessment measures to fill a safe-driving class (i.e., 15–27 participants which took approximately 2-3 weeks to recruit), participants were randomized to the BT group, the BT+OR group, or the BT+OR+S group using stratified randomization. Stratified randomization produces equal-sized study groups that are balanced by covariates (Kang, Ragan, & Park, 2008). Stratified randomization is applicable in this study because participants were identified before group assignment. In this instance, age and sex may have the potential to influence outcome variables. Therefore, to control the covariates of age (three levels: 65 to 69 years, 70 to 74 years, 75 years and above) and sex (two levels: male, female), six possible block combinations exist (e.g., 65 to 69 years, female; 75 years and above, male). Each participant was assigned to the appropriate block of covariates, and then simple randomization using SPSS software was utilized to assign the participants within each block to one of the study groups.

All participants received the in-class education component together. Upon in-class completion, all participants completed the driving knowledge evaluation for a second time. Participants assigned to the

BT group completed post-assessment measures (i.e., the Driving Comfort Scales and on-road driving evaluation) four to eight weeks after completion of the in-class education component, to ensure the same amount of time passed between pre- and post-assessments compared to the other two intervention groups. BT group participants were given the opportunity to receive the on-road practice sessions three months after they completed their post-assessment measures. Participants assigned to the BT+OR group further received two 45-minute on-road practice sessions. Those assigned to the BT+OR+S group also received two 45-minute on-road practice sessions and one 45-minute simulator-training session. Upon training completion, these participants completed post-assessment measures (i.e., the Driving Comfort Scales and on-road driving evaluation).

Once pre- and post-assessment measures were collected, the on-road driving evaluation videos were stored on a password-protected portable hard drive and sent to the University of Manitoba via mail. Each video was labelled with the participant's unique identification number, followed by an H or a T. The H and T represent "heads" or "tails," reflecting the outcome of a simple coin toss to randomize the participant's pre- and post-intervention video labels. This kept the RA scoring the on-road driving evaluation videos blind to whether the video is a pre- or post-intervention measure. Videos were only sent to the University of Manitoba once all participants' in a session completed their designated training to ensure the RAs scoring the on-road driving evaluation videos are also blind to group allocation.

Statistical Analysis

Sample size calculations. To calculate power and sample size, we determined that a clinically important difference would be a 10% reduction in unsafe-driving actions for the BT+OR group, based on previous findings (Bédard et al., 2008). Further, we determined that a clinically important difference would be a 20% reduction in unsafe-driving actions for the BT+OR+S group, because this is the most intensive intervention group in terms of training components. There were three contrasts (i.e., BT group vs. BT+OR group, BT group vs. BT+OR+S group, and BT+OR group vs. BT+OR+S group). Using SPSS software, assuming a mean of 100 for pre-intervention unsafe-driving actions, a standard deviation of 15, and an alpha value of 0.05, a correlation of 0.80, and a minimum power of 80%, sample size was calculated. To maximize power for all three contrasts, the sample size required was 25 for each intervention group (75 in total). This provided 100% power for the BT group vs. BT+OR+S group contrast, 82% power for the BT group vs. BT+OR group contrast, and 82% power for the BT+OR group vs. BT+OR+S group contrast. SPSS output for sample size calculations can be found in Appendix J.

Participant characteristics. To describe participants' characteristics, the range, mean, and standard deviation are reported for scaled variables (e.g., age, MMSE score, age started driving). The number and percentage falling in each category are reported for categorical variables (e.g., sex, miles driven per week, years since last crash).

Primary analysis. The primary analysis compares the driving evaluation scores (post-intervention) across groups using baseline scores as a covariate. To analyze differences across the three study groups, we used an analysis of covariance (ANCOVA) with post-intervention on-road driving scores (total and by sub-score) as the outcome variable, baseline on-road driving scores as the covariate, and training intervention group as the fixed factor. In this instance, there were three contrasts (i.e., BT group vs. BT+OR group, BT group vs. BT+OR+S group, and BT+OR group vs. BT+OR+S group). If a participant's vehicle was not equipped to support the in-vehicle recording device, they were excluded from the compliance error sub-score analysis. To adjust for multiple comparisons (i.e., to identify if any intervention group's post-intervention on-road driving scores differed significantly from other group post-intervention on-road driving scores), Fisher's least significant difference (LSD) method was used.

Secondary analyses. The secondary analyses compares the driving comfort levels (post-intervention) across groups using baseline scores as the covariates. To analyze differences across the three study groups, we use ANCOVA with driving comfort level post scores as the outcome variables, baseline driving comfort levels scores as the covariates, and training intervention group as the factors. There were three contrasts (i.e., BT group vs. BT+OR group, BT group vs. BT+OR+S group, and BT+OR group vs. BT+OR+S group).

In addition, driving knowledge evaluation pre- and post-classroom scores were compared using a paired t-test. Because all participants are administered this questionnaire at the same time point (i.e., after attending the in-class education component), group contrasts were not required.

Additional analyses. Further, correlational analyses were performed between baseline outcome measures (e.g., driving comfort levels, driving knowledge, and on-road driving score) and the change in participants' pre- and post-intervention on-road driving evaluation scores to determine whether baseline scores are related to change scores.

Intention-to-treat analysis. Because the aim of the present research was to determine the effectiveness of the driving training interventions on improving on-road driving performance in older adults, an intention-to-treat (ITT) analysis was used; that is, the analysis included every participant who was randomized according to their randomized treatment assignment, regardless of noncompliance or training intervention deviations (Fisher et al., 1990). For instance, if a participant in the BT+OR+S group did not complete the full simulator training session, they were still analyzed as part of the BT+OR+S group. ITT analysis avoids overoptimistic estimates of the effectiveness of the training interventions by accepting that noncompliance and training intervention deviations are likely to occur in the real world (Heritier, Gebski, & Keech, 2003).

Results

Participant Characteristics

The participants' (n=78) characteristics, by study group and overall, are presented in Table 1. The overall average age was 72.45 years (SD=5.34), with a range of 65–88 years. The majority of participants were women (74.4%). The mean SMMSE score was 28.78 (SD=1.62), with a range of 25–30. The average age at which participants started driving was 18.38 years (SD=6.27), with a range of 10–57 years. There were no differences between the three intervention groups on age, sex, SMMSE score, and age started driving.

Table 1: Participants' characteristics

Characteristic	BT (n=27)	BT+OR (n=25)	BT+OR+S (n=26)	Total (n=78)
Age Range Mean (SD)	 65 - 86 72.48 (6.25)	 66 - 88 72.60 (5.34)	 65 - 82 72.27 (4.43)	 65 - 88 72.45 (5.34)
Male (%)	7 (25.9)	6 (24.0)	7 (26.9)	20 (25.6)
SMMSE Range Mean (SD)	 25 - 30 28.89 (1.62)	 26 - 30 28.92 (1.44)	 25 - 30 28.54 (1.82)	 25 - 30 28.78 (1.62)
Age started driving Range Mean (SD)	 12 - 57 19.67 (9.38)	 10 – 35 17.40 (4.59)	 14 - 23 18.00 (2.56)	 10 - 57 18.38 (6.27)

Participants' driving history and habits, by study group and overall, as recorded by the Driving History/Habits questionnaire, are presented in Table 2. The use of block randomization allowed for similar distribution of driving frequency and driving comfort, as well as potential confounders, across the three intervention groups. A notable difference between the three intervention groups was in terms of restricted driving situations. A greater number of participants in the BT group tended to restrict their driving to daytime (18.5%) and local routes (7.4%) only, compared to the BT+OR (daytime: 12.0%; local routes: 0%) and BT+OR+S (daytime: 7.7%; local routes: 3.8%) groups. However, these differences are attributed to a very small number of participants.

Table 2: Participants' driving history and habits

	BT (n=27)	BT+OR (n=25)	BT+OR+S (n=26)	Total (n=78)
Kilometres driven per week (n [%]):				
0-20 km	2 (7.4)	3 (12.0)	1 (3.8)	6 (7.7)
21-50 km	8 (29.6)	5 (20.0)	9 (34.6)	22 (28.2)
51-100 km	8 (29.6)	11 (44.0)	8 (30.8)	27 (34.6)
Over 100 km	9 (33.3)	6 (24.0)	8 (30.8)	23 (29.5)
Number of at-fault crashes				
Range	0 – 3	0 – 6	0 – 3	0 – 6
Mean (SD)	0.59 (0.97)	0.84 (1.31)	0.65 (0.89)	0.69 (1.01)
Length of time since last at-fault crash (n, [%]):				
Less than 1 year	0 (0)	1 (4.0)	2 (7.7)	3 (3.8)
1-2 years	0 (0)	0 (0)	3 (11.5)	3 (3.8)
2-3 years	0 (0)	0 (0)	1 (3.8)	1 (1.3)
3-4 years	0 (0)	0 (0)	0 (0)	0 (0)
4-5 years	1 (3.7)	0 (0)	0 (0)	1 (1.3)
5-10 years	1 (3.7)	3 (12.0)	0 (0)	4 (5.1)
More than 10 years	10 (37.0)	8 (32.0)	5 (19.2)	23 (29.5)
Never had an accident	15 (55.6)	13 (52.0)	15 (57.7)	43 (55.1)
Number of not-at-fault crashes				
Range	0 – 4	0 – 3	0 – 3	0 – 4
Mean (SD)	1.11 (1.12)	0.84 (1.31)	0.96 (0.87)	0.97 (1.02)
Length of time since last not-at -fault crash (n, [%]):				
Less than 1 year	3 (11.1)	0 (0)	3 (11.5)	6 (7.7)
1-2 years	3 (11.1)	0 (0)	2 (7.7)	5 (6.4)
2-3 years	1 (3.7)	1 (4.0)	1 (3.8)	3 (3.8)
3-4 years	2 (7.4)	0 (0)	1 (3.8)	3 (3.8)
4-5 years	1 (3.7)	2 (8.0)	0 (0)	3 (3.8)
5-10 years	1 (3.7)	0 (0)	4 (15.4)	5 (6.4)
More than 10 years	7 (25.9)	9 (36.0)	6 (23.1)	22 (28.2)
Never had an accident	9 (33.3)	13 (52.0)	9 (34.6)	31 (39.7)
Number of times per week spent driving for (mean, [SD]):				
Groceries	2.41 (1.80)	1.96 (1.24)	1.88 (1.03)	2.09 (1.41)
Other shopping	1.96 (1.89)	1.36 (1.25)	1.19 (1.02)	1.51 (1.47)
Health-related appointments	0.15 (0.36)	0.28 (0.46)	0.27 (0.64)	0.23 (0.48)
Social events	3.19 (2.15)	2.88 (2.07)	2.42 (2.00)	2.83 (2.07)
Worship	0.37 (0.84)	0.44 (0.71)	0.38 (0.75)	0.40 (0.76)
Hobby-related	1.15 (1.72)	1.84 (1.93)	0.69 (1.22)	1.22 (1.70)
Work, school, or volunteering	1.11 (1.97)	1.28 (1.97)	1.04 (1.15)	1.14 (1.72)
Family Events	1.44 (1.76)	1.08 (1.63)	0.69 (0.88)	1.08 (1.49)
Other	0.11 (0.42)	0.48 (1.34)	0.38 (1.39)	0.32 (1.13)

Stressful/uncomfortable driving situations (n, [%]):				
Turning left at intersections	11 (40.7)	3 (12.0)	7 (26.9)	21 (26.9)
Driving at night	14 (51.9)	12 (48.0)	12 (46.2)	38 (48.7)
Backing up	7 (25.9)	7 (28.0)	8 (30.8)	22 (28.2)
Parallel parking	10 (37.0)	6 (24.0)	6 (23.1)	22 (28.2)
Driving in unfamiliar areas	13 (48.1)	11 (44.0)	14 (53.8)	38 (48.7)
Driving with passengers	3 (11.1)	2 (8.0)	2 (7.7)	7 (9.0)
Driving alone	0 (0)	0 (0)	0 (0)	0 (0)
Navigating parking lots	5 (18.5)	3 (12.0)	5 (19.2)	13 (16.7)
Changing lanes	8 (29.6)	2 (8.0)	7 (26.9)	17 (21.8)
Maintaining the speed limit	3 (11.1)	2 (8.0)	4 (15.4)	9 (11.5)
Driving in bad weather	18 (66.7)	17 (68.0)	11 (42.3)	46 (59.0)
Driving in heavy traffic	8 (29.6)	11 (44.0)	11 (42.3)	30 (38.5)
Other	11 (40.7)	8 (32.0)	8 (30.8)	27 (34.6)
None of the above	1 (3.7)	1 (4.0)	0 (0)	2 (2.6)
Restricted driving situations (n, [%]):				
Daytime	5 (18.5)	3 (12.0)	2 (7.7)	10 (12.8)
When accompanied by passenger	0 (0)	0 (0)	0 (0)	0 (0)
Outside of rush hour	1 (3.7)	2 (8.0)	0 (0)	3 (3.8)
Local routes	2 (7.4)	0 (0)	1 (3.8)	3 (3.8)
Fair weather	3 (11.1)	3 (12.0)	3 (11.5)	9 (11.5)
Other	0 (0)	0 (0)	0 (0)	0 (0)
None of the above	20 (74.1)	16 (64.0)	19 (73.1)	55 (70.5)
Speed on local streets (n, [%]):				
35 km/hr or less	0 (0)	0 (0)	0 (0)	0 (0)
36-45 km/hr	1 (3.7)	1 (4.0)	0 (0)	2 (2.6)
46-55 km/hr	23 (85.2)	18 (72.0)	22 (84.6)	63 (80.8)
56-65 km/hr	3 (11.1)	6 (24.0)	4 (15.4)	13 (16.7)
66 km/hr or more	0 (0)	0 (0)	0 (0)	0 (0)
Speed on major highways (n, [%]):				
85 km/hr or less	1 (3.7)	0 (0)	0 (0)	1 (1.3)
86-95 km/hr	12 (44.4)	10 (40.0)	11 (42.3)	33 (42.3)
96-105 km/hr	13 (48.1)	14 (56.0)	14 (53.8)	41 (52.6)
106-115 km/hr	1 (3.7)	1 (4.0)	1 (3.8)	3 (3.8)
116 km/hr or more	0 (0)	0 (0)	0 (0)	0 (0)

Participants' driving history profile, by study group and overall, as measured by the Driving History Profile questionnaire, are presented in Table 3. The use of block randomization allowed for similar distribution of driving history (e.g., driving restrictions, use of alternative transportation, number of traffic citations), as well as potential confounders, across the three intervention groups. There were no notable differences between the three intervention groups in terms of driving history.

Table 3: Participants' driving history profile

	BT (n=27)	BT+OR (n=25)	BT+OR+S (n=26)	Total (n=78)
Days driven per week	3 - 7 5.81 (1.44)	3 - 7 5.92 (1.50)	3 - 7 5.81 (1.56)	3 - 7 5.85 (1.49)
Common passengers (n, [%]):				
Spouse/partner	10 (37.0)	13 (52.0)	13 (50.0)	36 (46.2)
Family member	5 (18.5)	8 (32.0)	2 (7.7)	15 (19.2)
Friend	7 (25.9)	8 (32.0)	4 (15.4)	19 (24.4)
Caregiver	0 (0)	0 (0)	0 (0)	0 (0)
Other	2 (7.4)	0 (0)	0 (0)	2 (2.6)
No one	20 (74.1)	18 (72.0)	21 (80.8)	59 (75.6)
Limited ability to drive due to (n, [%]):				
Health condition	3 (11.1)	2 (8.0)	3 (11.5)	8 (10.3)
Taking medications	0 (0)	0 (0)	0 (0)	0 (0)
Tested in the last year (n, [%]):				
Vision	23 (85.2)	20 (80.0)	23 (88.5)	66 (84.6)
Hearing	6 (22.2)	7 (28.0)	4 (15.4)	17 (21.8)
Physical exam/checkup	19 (70.4)	22 (88.0)	24 (92.3)	65 (83.3)
Completed car maintenance in the last year (n, [%]):				
Oil change	25 (92.6)	24 (96.0)	26 (100.0)	75 (96.2)
Checking tires	26 (96.3)	25 (100.0)	26 (100.0)	77 (98.7)
Checking fluid levels	25 (92.6)	25 (100.0)	26 (100.0)	76 (97.4)
Checking headlights, brake lights, and parking lights	25 (92.6)	25 (100.0)	26 (100.0)	76 (97.4)
Avoided driving situations (n, [%]):				
Rush hour/heavy traffic	7 (25.9)	7 (28.0)	5 (19.2)	19 (24.4)
Interstate/highway driving	5 (18.5)	2 (8.0)	3 (11.5)	10 (12.8)
Rain	2 (7.4)	1 (4.0)	1 (3.8)	4 (5.1)
Night-time driving	12 (44.4)	10 (40.0)	9 (34.6)	31 (39.7)
Left hand turns against traffic	3 (11.1)	3 (12.0)	4 (15.4)	10 (12.8)
Other	3 (11.1)	5 (20.0)	2 (7.7)	10 (12.8)
None	11 (40.7)	5 (20.0)	9 (34.6)	25 (32.1)
Use of alternative transportation (n, [%]):				
Always	0 (0)	0 (0)	0 (0)	0 (0)
Often	1 (3.7)	0 (0)	0 (0)	1 (1.3)
Sometimes	1 (3.7)	3 (12.0)	2 (7.7)	6 (7.7)
Rarely	6 (22.2)	3 (12.0)	6 (23.1)	15 (19.2)
Never	19 (70.4)	19 (76.0)	18 (69.2)	56 (71.8)
Would consider alternative transportation if more available (n, [%]):	8 (29.6)	8 (32.0)	11 (42.3)	27 (34.6)
Frequency of breaks on long trips (n, [%]):				
Every 1 to 2 hours	15 (55.6)	14 (58.3)	10 (38.5)	39 (50.6)
Every 3 to 4 hours	10 (37.0)	10 (41.7)	16 (61.5)	36 (46.8)
Every 5 to 6 hours	1 (3.7)	0 (0)	0 (0)	1 (1.3)
Rarely or Never	1 (3.7)	0 (0)	0 (0)	1 (1.3)

Difficulty fastening seatbelt (n, [%]):				
Always	0 (0)	0 (0)	0 (0)	0 (0)
Often	0 (0)	0 (0)	0 (0)	0 (0)
Sometimes	1 (3.7)	0 (0)	0 (0)	1 (1.3)
Rarely	2 (7.4)	1 (4.0)	0 (0)	3 (3.8)
Never	24 (88.9)	24 (96.0)	26 (100.0)	74 (94.9)
Number of crashes in the past 3 years				
Range	0-2	0-1	0-2	0-2
Mean (SD)	1.14 (0.38)	1.00 (0)	1.10 (0.32)	1.11 (0.32)
Number of moving violations, citations, or traffic tickets in the past 3 years				
Range	0-1	0-1	0-2	0-2
Mean (SD)	0.15 (0.36)	0.12 (0.33)	0.12 (0.43)	0.13 (0.37)
Last attendance in a driver education, training or retraining course(n, [%]):				
Within the past year	1 (3.7)	1 (4.0)	2 (7.7)	4 (5.1)
1-3 years ago	2 (7.4)	0 (0)	1 (3.8)	3 (3.8)
More than 3 years ago	9 (33.3)	11 (44.0)	10 (38.5)	30 (38.5)
Never	15 (55.6)	13 (52.0)	13 (50.0)	41 (52.6)
Type of driver education, training or retraining course (n, [%]):				
On-line class	0 (0)	0 (0)	0 (0)	0 (0)
Classroom course for all drivers	2 (16.7)	2 (16.7)	3 (23.1)	7 (18.9)
Classroom course for mature drivers	2 (16.7)	3 (25.0)	4 (30.8)	9 (24.3)
Course with classroom and behind the wheel instruction	5 (41.7)	5 (41.7)	4 (30.8)	14 (37.8)
Other	3 (25.0)	2 (16.7)	2 (15.4)	7 (18.9)
Means to keeping up with changes in road rules or laws (n, [%]):				
Driving class	2 (7.4)	1 (4.0)	2 (7.7)	5 (6.4)
Newspaper	16 (59.3)	16 (64.0)	19 (73.1)	51 (65.4)
TV	13 (48.1)	11 (44.0)	14 (53.8)	38 (48.7)
Driver’s handbook	4 (14.8)	5 (20.0)	4 (15.4)	13 (16.7)
Friends or family	12 (44.4)	9 (36.0)	11 (42.3)	32 (41.0)
Computer	7 (25.9)	4 (16.0)	3 (11.5)	14 (17.9)
Police or law enforcement	3 (11.1)	1 (4.0)	2 (7.7)	6 (7.7)
Driver’s license office	3 (11.1)	4 (16.0)	5 (19.2)	12 (15.4)
Other	0 (0)	1 (4.0)	0 (0)	1 (1.3)

On-Road Driving Evaluation Scores

The participants' on-road driving scores, by intervention group, were compared using an ANCOVA. It is important to note that a large number of participants (n=13) in the BT+OR+S group were unable to complete the entire simulator-training session due to simulator sickness, or simulator adaptation syndrome. Simulator sickness is a type of motion sickness that occurs in simulators, and includes symptoms of disorientation and nausea (Johnson, 2005). Results are presented in Table 4. The on-road driving evaluation is divided according to four categories of safe-driving practices, including 1) vehicle controls; 2) procedural; 3) observations; and 4) compliance errors. One point was assigned for each unsafe-driving action. As such, a higher on-road driving score indicates a greater number of unsafe-driving actions committed. If a participant's vehicle was not equipped to support the in-vehicle recording device, they were excluded from the compliance error sub-score analysis. Nine participants were excluded for this reason. Mean baseline total on-road driving scores were similar for intervention groups, averaging 129.78 (SD=29.87) for the BT group, 128.48 (SD=20.15) for the BT+OR group, and 127.73 (SD=24.24) for the BT+OR+S group. At baseline, the greatest numbers of unsafe-driving actions were recorded in the vehicle controls (e.g., signalling, hand position) and observations (e.g., mirrors, blind spots) sub-scores.

Table 4: Comparison of on-road driving scores (total and sub-scores) by intervention group

On-road driving score	**Group**	**Baseline** Mean (SD)	**Post-intervention** Mean (SD)	**Raw Change** Mean (95% CI)	**F**	***p*-value**
Vehicle Control	BT	24.30 (17.92)	22.78 (18.21)	-1.52 (-7.59, 4.55)	4.93	.010
	BT+OR	20.84 (16.01)	10.44 (12.83)	-10.40 (-15.71, -5.09)		
	BT+OR+S	22.00 (18.23)	12.42 (16.06)	-9.58 (-16.90, -2.26)		
Procedural	BT	7.78 (3.64)	5.93 (3.67)	-1.85 (-2.92, -0.78)	2.58	.082
	BT+OR	6.72 (3.48)	3.60 (3.11)	-3.12 (-4.84, -1.40)		
	BT+OR+S	6.81 (3.57)	4.38 (3.16)	-2.42 (-3.79, -1.05)		
Observations	BT	90.44 (15.21)	86.67 (16.73)	-3.78 (-6.97, -0.58)	13.48	<.001
	BT+OR	92.08 (8.66)	67.36 (18.00)	-24.72 (-31.88, -17.56)		
	BT+OR+S	90.35 (14.74)	65.42 (21.95)	-24.92 (-34.28, -15.56)		
Compliance Errors*	BT	9.48 (3.42)	7.22 (3.37)	-2.26 (-3.53, -0.99)	1.24	.296
	BT+OR	8.70 (3.66)	5.75 (2.38)	-2.95 (-5.13, -0.77)		
	BT+OR+S	8.73 (4.37)	7.23 (4.17)	-1.50 (-3.68, 0.68)		
Total	BT	129.78 (29.87)	122.59 (32.22)	-7.18 (-14.26, -0.11)	15.74	<.001
	BT+OR	128.48 (20.15)	86.84 (25.52)	-41.64 (-53.29, -26.21)		
	BT+OR+S	127.74 (24.24)	89.04 (30.28)	-38.69 (-52.16, -22.20)		

*Note: Participants' whose vehicle was not equipped to support the in-vehicle recording device were excluded from the compliance error sub-score analysis (n=9).

There was a significant effect of intervention group on total post-intervention on-road driving scores ($F(2, 74) = 15.74$, $p < .001$), vehicle control post-intervention sub-scores ($F(2, 74) = 4.93$, $p = .010$), and observation post-intervention sub-scores ($F(2, 74) = 13.48$, $p < .001$), after controlling for the effect of baseline on-road driving scores. There was not a significant effect of intervention group on procedural post-intervention sub-scores ($F(2, 74) = 2.58$, $p = .082$) or compliance error post-intervention sub-scores ($F(2, 74) = 1.24$, $p = .296$), after controlling for the effect of baseline on-road driving scores.

There was also a significant effect of kilometers driven per week on total post-intervention on-road driving scores ($F(3, 71) = 2.98$, $p = .037$). However, kilometers driven per week did not interact with intervention group ($F(6,65) = 1.94$, $p = .087$), and including it in the model had no important effect on the F-test for intervention group or any contrasts involving intervention group.

For post-intervention on-road driving scores for which there was a significant effect of intervention group (i.e., total score and vehicle control and observations sub-scores), Fisher's LSD method was used to adjust for multiple comparisons (i.e., to identify which intervention groups differed significantly from other intervention groups in their mean post-intervention on-road driving scores). Results are presented in Table 5. For total post-intervention on-road driving scores, a significant difference was observed between the BT group and both the BT+OR group (*p*<.001) and the BT+OR+S (*p*<.001) training groups. However, the BT+OR and BT+OR+S groups did not significantly differ (*p*=.707).

Table 5: Fisher's LSD contrast for post-intervention on-road driving scores

On-road driving score	**Group**	**Comparison Group**	**Difference in Post-intervention On-road Driving Score** Mean (95% CI)	***p*-value**
Vehicle Control	BT	BT+OR	10.56 (3.21, 17.90)	.005
	BT	BT+OR+S	9.17 (1.92, 16.42)	.014
	BT+OR	BT+OR+S	-1.38 (-8.77, 6.00)	.710
Observations	BT	BT+OR	20.42 (11.10, 29.74)	<.001
	BT	BT+OR+S	21.18 (11.96, 30.40)	<.001
	BT+OR	BT+OR+S	0.76 (-8.65, 10.17)	.873
Total	BT	BT+OR	34.94 (21.01, 48.88)	<.001
	BT	BT+OR+S	32.28 (18.47, 46.08)	<.001
	BT+OR	BT+OR+S	-2.67 (-16.73, 11.40)	.707

Driving Knowledge

The driving knowledge questionnaire was administered at pre-assessment and immediately following the in-class training component to all participants. The same questions were administered at both time points, and correct answers were not provided until after the post-training questionnaire was completed. The results of the in-class training component on the knowledge of the participants were evaluated by comparing their pre- and post-classroom knowledge scores using a paired t-test. This analysis revealed a statistically significant improvement after the in-class training component (t[df = 77] = 5.75, p<.001). An increase from 74.4% (SD=12.4) of questions answered correctly at baseline to 83.2% (SD=12.2) at post-classroom was observed.

Driving Comfort Scales

The participants' driving comfort levels, by intervention group, as measured by the 13-item day (DCS-D) and 16-item night (DCS-N) driving comfort scales were compared using an ANCOVA. Results are presented in Table 6. Total comfort scores on the DCS-D and DCS-N were computed by summing responses and then dividing by the number of items answered (Myers et al., 2008). Mean baseline daytime driving comfort levels were similar for intervention groups, averaging 62.46% (SD=22.08) for the BT group, 67.54% (SD=15.28) for the BT+OR group, and 60.28% (SD=22.84) for the BT+OR+S group. There was no significant effect of intervention group on either day or night post-intervention driving comfort levels after controlling for the effect of baseline comfort levels (day: $F(2, 74) = 0.998$, $p = .374$; night: $F(2, 74) = 0.348$, $p = .708$).

Table 6: Comparison of driving comfort levels by group

Driving Comfort Scale	**Group**	**Baseline (%)** Mean (SD)	**Post-intervention (%)** Mean (SD)	**Raw Change (%)** Mean (95% CI)	**F**	***p-value***
Daytime (DCS-D)	BT	62.46 (22.08)	64.24 (18.29)	1.78 (-6.67, 10.23)	0.998	.374
	BT+OR	67.54 (15.28)	71.38 (12.43)	3.85 (-2.53, 10.22)		
	BT+OR+S	60.28 (22.84)	62.94 (19.27)	2.66 (-3.54, 8.86)		
Nighttime (DCS-N)	BT	50.06 (25.60)	54.34 (24.91)	4.28 (-4.77, 13.34)	0.348	.708
	BT+OR	56.38 (20.72)	60.19 (19.23)	3.81 (-5.07, 12.70)		
	BT+OR+S	47.48 (22.45)	50.90 (20.92)	3.42 (-2.16, 9.01)		

Additional Analyses

A correlational analysis was performed to assess the relationship between baseline outcome measures (e.g., driving comfort levels, driving knowledge, and on-road driving score) and the change in participants' pre- and post-intervention on-road driving evaluation scores. Results, by intervention group and overall, are presented in Table 7. The change in participants' pre- and post-intervention on-road driving evaluation scores were calculated by subtracting the pre-intervention on-road driving evaluation score from the post-intervention on-road driving evaluation score. Because participants were assigned a point for each unsafe-driving action they committed, a negative change indicates a reduction in unsafe-driving actions, or an improvement in safe-driving behaviours. That is, the lower the value of an on-road driving evaluation score, the better the safe-driving performance.

Table 7: Correlation coefficients between various outcome measures and change in on-road driving evaluation scores by intervention group

Outcome Measure	Group	Pearson Correlation (r)	95% Confidence Interval	*p*-value
DCS-D	BT	-.047	-.419, .339	.815
	BT+OR	-.094	-.472, .313	.656
	BT+OR+S	-.115	-.481, .285	.576
	Overall	-.096	-.312, .129	.402
DSC-N	BT	-.254	-.578, .140	.201
	BT+OR	.132	-.278, .501	.528
	BT+OR+S	.282	-.119, .603	.163
	Overall	.047	-.177. .267	.680
Driving Knowledge	BT	-.312	-.618, .078	.113
	BT+OR	-.051	-.437, .351	.810
	BT+OR+S	-.060	-.437, .335	.769
	Overall	-.190	-.396, .034	.095
Baseline On-road Driving Evaluation Score	BT	-.162	-.510, .232	.418
	BT+OR	-.482	-.737, -.107	.015
	BT+OR+S	-.460	-.719, -.088	.018
	Overall	-.287	-.479, -.069	.011

A Pearson correlation coefficient was computed to assess the relationship between the participants' baseline driving comfort levels, as measured by the 13-item day (DCS-D) and 16-item night (DCS-N) driving comfort scales, and the change in participants' pre- and post-intervention on-road driving evaluation scores. Overall, there was no correlation between baseline daytime driving comfort levels and change in on-road driving evaluation scores (r= -.096, *p*=.402, 95% CI [-.312, .129]), and no correlation between baseline night-time driving comfort levels and change in on-road driving evaluation scores (r=.047, *p*=.680, 95% CI [-.177, .267]). A scatter plot of baseline driving comfort levels and change in on-road driving evaluation scores, by intervention group, can be seen in Figures 2 and 3.

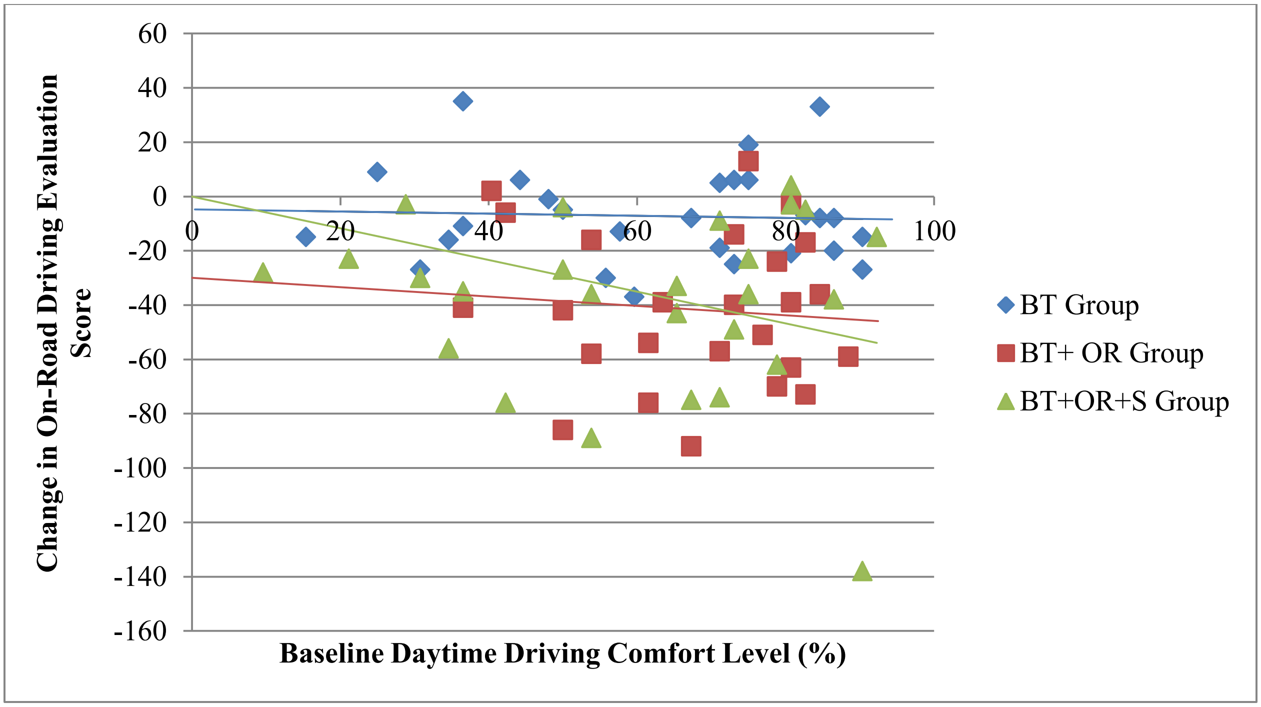

Figure 2. Scatter plot of baseline daytime driving comfort levels and change in on-road driving evaluation scores, by intervention group.

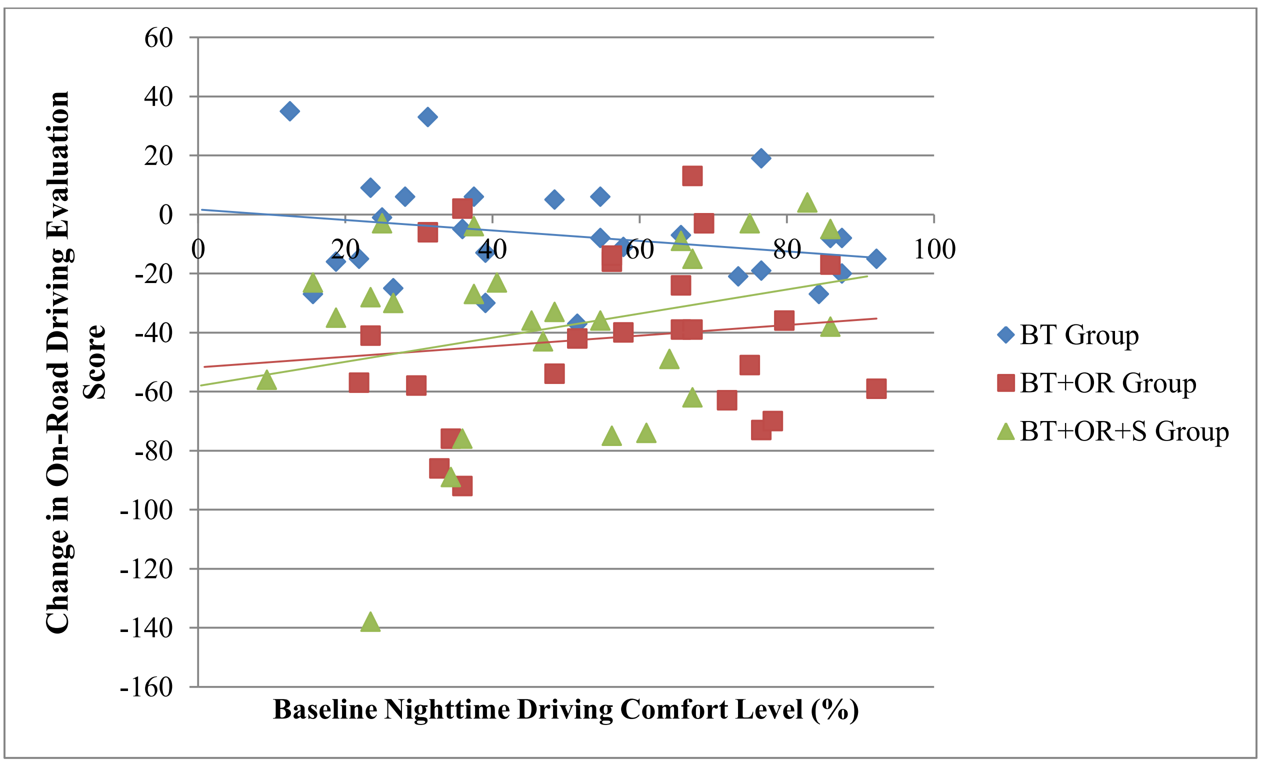

Figure 3. Scatter plot of baseline nighttime driving comfort levels and change in on-road driving evaluation scores, by intervention group.

A Pearson correlation coefficient was also computed to assess the relationship between participants' baseline driving knowledge, and the change in participants' pre- and post-intervention on-road driving evaluation scores. Overall, there was no correlation between baseline driving knowledge and change in on-road driving evaluation scores (r= -.190, *p*=.095, 95% CI [-.396, .034]). A scatter plot of baseline driving knowledge and change in on-road driving evaluation scores, by intervention group, can be seen in Figure 4.

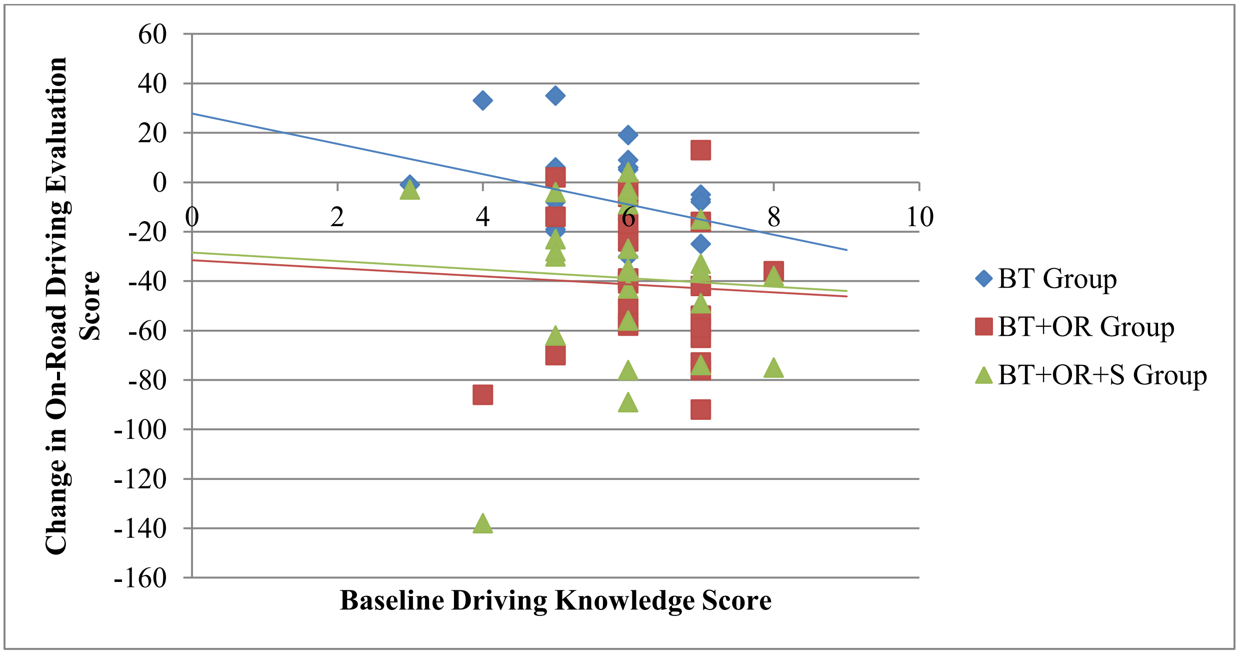

Figure 4. Scatter plot of baseline driving knowledge and change in on-road driving evaluation scores, by intervention group.

Finally, a Pearson correlation coefficient was computed to assess the relationship between participants' baseline on-road driving score and the change in participants' pre- and post-intervention on-road driving evaluation scores. In the BT group, there was no correlation between baseline on-road driving evaluation scores and change in on-road driving evaluation scores (r= -.162, *p*=.418, 95% CI [-.510, .232]). However, in the BT+OR and BT+OR+S groups, there were moderate negative correlations between baseline on-road driving evaluation scores and change in on-road driving evaluation scores (BT+OR: r= -.482, *p*=.015, 95% CI [-.737, -.107]; BT+OR+S: r= -.460, *p*=.018, 95% CI [-.719, -.088]), indicating drivers with lower baseline scores had greater improvements after receiving their designated interventions. A scatter plot of baseline on-road driving evaluation scores and change in on-road driving evaluation scores, by intervention group, can be seen in Figure 5.

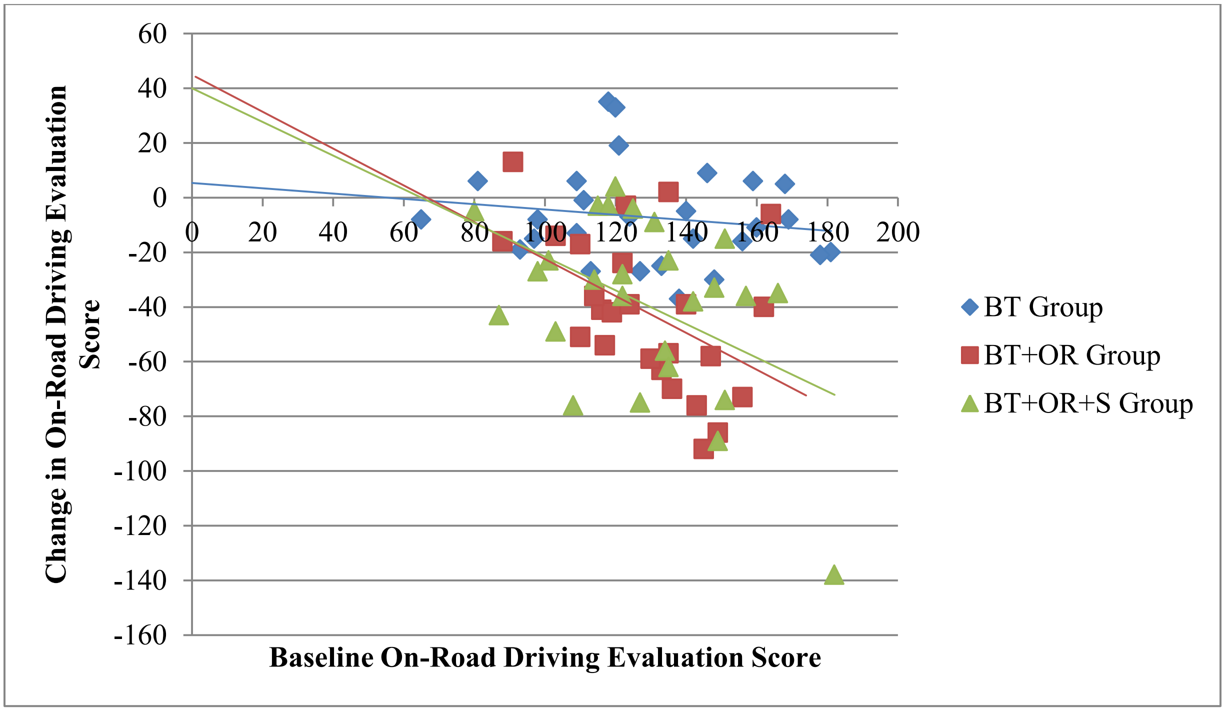

Figure 5. Scatter plot of baseline on-road driving evaluation scores and change in on-road driving evaluation scores, by intervention group.

Discussion

Previous research on driving training interventions for older adult drivers has had varying outcomes related to on-road driving performance. Classroom training supplemented with on-road driving or simulator training and individualized feedback has had the most consistent and beneficial influence on driving performance in older adult drivers. Therefore, it was a logical extension of previous research to examine both forms of training (i.e., on-road driving and simulator training) with individualized feedback simultaneously in order to determine if these forms of active training yield greater improvements in on-road driving performance when combined. Further, the present research also examines the impact of the training program on driving comfort levels and driving knowledge.

On-Road Driving Evaluation Scores

Analyses demonstrated that participants in the BT+OR and BT+OR+S groups significantly decreased their overall number of unsafe-driving actions relative to post-intervention unsafe-driving actions by the BT group. However, no significant group differences were found between the BT+OR and BT+OR+S groups' post-intervention unsafe-driving actions. Specifically, an examination of pre- and post-intervention group means of overall unsafe-driving actions revealed that the BT+OR group's unsafe-driving actions reduced by an average of 41.64 (32.4%) (95% CI [26.21, 53.29]) and the BT+OR+S group's unsafe-driving actions reduced by an average of 38.69 (30.3%) (95% CI [22.20, 52.16]) unsafe-driving actions, while the BT group's unsafe-driving actions only reduced by an average of 7.18 (5.5%) (95% CI [0.11, 14.26]). These results suggest that on-road training with a review of on-road driving evaluation videos and individualized feedback of on-road driving performance can improve on-road safe-driving performance in older adult drivers. This finding is consistent with components of previous research, including Bédard et al. (2008), who showed that participants who received in-class and on-road training improved in some aspects of safe driving. As well, Porter (2013) reported that participants who received video and GPS feedback in addition to classroom education significantly reduced their driving errors by 25% following the intervention. The combination of on-road training and individualized feedback of on-road driving performance in this study resulted in an even greater reduction in unsafe-driving actions.

However, the addition of simulator training with individualized feedback in the BT+OR+S group did not produce a greater reduction in unsafe-driving actions compared to the BT+OR group as hypothesized. Although past simulator-training interventions have yielded improvements in various components of on-road driving performance (Lavalliere et al., 2012; Romoser & Fisher, 2009), one tentative explanation may be that the simulator-training component implemented in this research study was not intensive enough to achieve noticeable impacts on on-road driving performance. For instance, a recent study examined the impact of ten active driving simulator-training sessions on on-road driving performance in 91 drivers, aged 62–87 years, using an RCT design (Casutt, Theill, Martin, Keller, & Jancke, 2014). Drivers who received the simulator-training intervention had significant improvement in on-road performance compared to a group that received no such training ($F(1,74)=2.86$, $p<0.05$) (Casutt et al., 2014). As such, more than one simulator-training session may have been necessary to achieve noticeable impacts. Another potential reason simulator training may not have yielded greater improvements in on-road driving performance compared to the BT+OR group is because a large number of participants (n=13) in the BT+OR+S group were unable to complete the entire simulator-training session due to simulator sickness. Since an ITT analysis was conducted, simulator sickness may have made the on-road driving evaluation scores in the BT+OR+S group more similar to the BT+OR group. Casutt and colleagues (2014) also found simulator sickness to be a problem in their research, but reported that average sickness diminished as simulator training progressed throughout the ten sessions. Though, simulator sickness is highly prevalent in older adult drivers. For instance, Freund and Green (2006) reported that almost 11% of older drivers in their study, aged 60 to 99 years, reported experiencing simulator sickness, and more than half (57%) of their participants were unable to complete a simulated drive. Therefore, because simulator sickness is common in this study population, it may not be rational to include this form of training in a real-world setting.

In regards to this study's primary hypothesis, participants in the BT+OR group did perform fewer unsafe-driving actions after training than participants in the BT group. However, participants in the BT+OR+S group did not perform fewer unsafe-driving actions after training than participants in the BT+OR group, only the BT group.

Driving Knowledge

Driving knowledge was assessed for all participants at the same time-point, directly after completing the in-class training component. The analysis revealed an overall statistically significant improvement in driving knowledge after the in-class training component; that is, there was an increase from 74.4% to 83.2% of questions answered correctly before receiving the in-class training component to after receiving the in-class training component. This finding is consistent with past research studies that have found an improvement in driving knowledge after attending classroom driving education (Marottoli et al., 2007). Therefore, in regards to the study's secondary hypothesis, all participants did appear to possess greater driving knowledge after completion of the in-class training component.

Driving Comfort Scales

Analyses revealed there were no significant differences between the three driving training intervention groups in post-intervention day and night driving comfort levels. Although all driving training intervention groups did slightly improve in both day and night driving comfort levels after receiving their designated training, these improvements were minor. For instance, daytime driving comfort only improved from 62.5% to 64.2% in the BT group, 67.5% to 71.4% in the BT+OR group, and 60.3% to 62.9% in the BT+OR+S group. Night-time driving comfort only improved from 50.1% to 54.3% in the BT group, 56.4% to 60.2% in the BT+OR group, and 47.5% to 50.9% in the BT+OR+S group. However, as previously mentioned, confidence in driving ability actually bears little relationship to on-road performance (Marottoli & Richardson, 1998; Riendeau et al., 2014). Therefore, in regards to the study's secondary hypothesis, driving confidence, as conceptualized by comfort in various driving situations, remained equal between intervention groups before and after receiving designated training.

Because our driving training interventions were designed to improve on-road driving performance, it is not surprising that the interventions did not dramatically affect driving comfort levels. Should future studies aim to address the impacts of driving training interventions on driving comfort, they may wish to focus their training on situations which older adult drivers find most uncomfortable, including driving at night, driving in unfamiliar areas, and driving in bad weather.

Additional Analyses

Additional analyses revealed there was no correlation, overall or by intervention group, between participants' baseline day and night driving comfort levels or participants' baseline driving knowledge, and the change in participants' pre- and post-intervention on-road driving evaluation scores. These findings suggest that the level of driving comfort and knowledge at baseline do not have any effect on whether greater changes in on-road driving evaluation scores can be achieved after receiving driving training interventions. However, analyses did demonstrate that BT+OR and BT+OR+S group participants' baseline on-road driving scores were inversely correlated with change in participants' pre- and post-intervention on-road driving evaluation scores, while there was no correlation between these scores in the BT group. This finding suggests that participants with poorer baseline on-road driving scores achieved greater improvements between pre- and post-intervention on-road driving evaluation scores if they were in the BT+OR and BT+OR+S groups. These findings are similar to those discussed by Bédard et al. (2004), who also found a statistically significant relationship between baseline on-road driving scores and on-road driving change scores (r [63]=-0.42, p=.001) following classroom driving training, suggesting participants who scored lower at baseline experienced greater improvements at follow up. This finding was expected, because those with poorer pre-intervention on-road driving evaluation scores have more room for improvement than those who already show strong driving performance at baseline. In the future, more advanced or tailored training may be required to improve driving performance in participants who have better on-road driving evaluation scores at baseline.

Strengths

The present study used an RCT design, which is considered the gold standard scientific method for comparing intervention effectiveness. Specifically, the present study included components to address numerous threats to internal validity. For instance, the randomization of participants, based on age and sex, helped to ensure that groups were equivalent with respect to baseline and outcome variables, as well as unmeasured potential confounders. Further, the use of a single independent rater to score on-road driving evaluation videos, who was blinded to group allocation and pre- and post-intervention status, ensured an objective and consistent rating of the primary outcome measure.

Another strength of this study, similar to that mentioned by Porter (2013), is the nature of the on-road driving evaluation. The use of video and GPS technology to record the on-road driving evaluations negated the requirement of an in-vehicle driving examiner. The absence of an in-vehicle driving examiner may have allowed for a more accurate representation of participants' unsafe-driving actions, as an in-vehicle driving examiner may have greater difficulty recording every action in real time. Further, providing a standardized driving route with identical maneuvers to each participant permits a true comparison of on-road driving performance.

Limitations and Directions for Future Research

Despite the positive findings of this study, there are also a number of limitations that merit further research to be conducted. First, all participants of the present study were recruited on a volunteer basis. As such, volunteer bias may exist in the present study; that is, older adults who volunteered to participate in the present study may be different from the general older adult population (Boughner, 2010). For instance, participants may have only represented drivers who were not afraid to have their driving evaluated. As such, the findings may not be generalizable to all older adult drivers. Further, all participants were recruited from Thunder Bay, Ontario, where driving situations are much different compared to larger Canadian cities. Therefore, this may also influence the generalizability of the present study. To increase generalizability of the findings, it may be beneficial to repeat the same training interventions in different settings across Canada.

In addition, it could not be determined whether it was the on-road driving training, the review of the on-road driving evaluation videos with individualized feedback, or both elements combined, that produced the greater reduction in unsafe-driving actions in the BT+OR and BT+OR+S groups. Therefore, future research should attempt to further separate these training components to verify the attributable influences of each on-road driving performance in older adult drivers.

Further, additional factors that may impact on-road driving performance should be accounted for in future studies. Although the present study collected general information regarding cognitive performance and overall health, this was only to ensure that intervention groups did not differ in regards to these factors. However, future studies should assess the effects that certain cognitive (e.g., executive functioning), physical (e.g., eye sight), and health (e.g., diabetes mellitus) declines sometimes associated with aging have on change in on-road driving evaluation scores. This could potentially lead to knowledge regarding targeted interventions for certain subgroups of the older adult driver population.

It will also be important to determine the impact of the driving training interventions on additional outcomes related to driving; for instance, the impact of the driving training interventions on driving frequency, to ensure that unnecessary driving restriction does not occur as a result of receiving the more intensive driving training interventions. Also, because the ultimate aim of our study was to determine the effectiveness of driving training to enhance safe-driving behaviour in older adults, it will be important to determine how much of an improvement in on-road driving evaluation scores actually improves driving safety, such as a reduction in crash risk. Longitudinal study designs must be implemented to determine if the present study's driving training interventions can achieve this goal. In addition, it may be beneficial to assigned weighted values to each unsafe-driving action during the on-road driving evaluation. This may allow for greater predictive ability of motor vehicle crashes.

Finally, it will be important to determine the effects of the present study's driving training interventions over time; that is, will they result in continued improvement, stability, or decay months after training is complete? Future research to assess the driving training intervention's trajectories over time is needed.

Conclusion

The present study suggests that on-road driving training with individualized feedback can result in considerable improvements in on-road driving performance in older adult drivers. As such, this form of driving training intervention should be the focus of more inquiry. Further, the training components that were investigated appeared to have no impact on driving comfort levels. In order to influence driving comfort levels, training interventions that are targeted towards comfort require further investigation. Finally, the in-class training component increased driving knowledge in older adult drivers, a finding consistent with past classroom training intervention investigations.

Improving on-road driving performance in older adult drivers has considerable benefits to both the automotive industry and Canadians. First, older adult drivers will represent a large portion of the automotive industry's market in coming years. Keeping older adult drivers on the road for as long as possible sustains this market. Second, safer on-road driving performance may lead to a reduction in crashes with the resulting injury prevention and economic benefits (i.e., lower insurance rates), not only for older adult drivers, but other road users as well. Third, safer driving behaviours can lead to prolonged use of the automobile, with resulting quality-of-life benefits for older adult drivers and their families. For example, older adults would be able to remain active and social without having to rely on family members for transportation needs. The numerous beneficial implications of this research necessitate further research in this area in order to develop a driving training program that can be implemented in the real world, to keep older drivers on the road for as long as possible, as safely as possible.

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Appendix A: Mini-Mental Status Examination

Score	Max. Score	Items
	5	**What is the: year, season, date, day, month?**
	5	**Where are we: state, county, city, hospital, floor (home, room)?**
	3	**Registration Apple, Table, Penny.** Name three objects: One second to say each. Then ask the patient all three after you have said them. Give one point for each correct answer. Repeat them until he learns all three. Count trials and record number. Number of Trials: _______
	5	**Attention and Calculation 100: 93, 86, 79, 72, 65** Begin with 100 and count backwards by 7 after five answers.
	3	**Recall Apple, Table, Penny.** Ask for the three objects repeated above. Give one point for each correct answer.
	 2 1 3 1	Language **Show a pencil and a watch and ask subject to name them.** **Repeat the following: "No ifs, ands, or buts".** **A three-stage command, "Take a paper in your right hand, fold it in half, and put it on the floor".** **Read and obey the following: (show subject the written item).** Close your eyes
	1 1	**Write a sentence.** **Copy a design (complex polygon as in Bender-Gestalt).**
	30	Total score possible

oValid oInvalid

Instruction: If a participant scores less than 24/30 on the MMSE, do NOT proceed with the road test.

Appendix B: G2 Exit Road Test Maneuvers

Traffic Adherences G2 Test	#
Total Unprotected Left Turns	5
Total Fully Protected Left Turns	3
Total Left Turns	**8**
Total Left onto 1 lane	4
Total Left onto 2 lanes	4
Total on-ramp	3
Total Right onto 1 lane	4
Total Right onto 2 lanes	6
Total Right Turns	**10**
Total Lane changes	2
Total Flashing Yellow lights	0
Straight Through Traffic Light	2
Straight Through Stop Sign	1
Left Stop Sign	3
Right Stop Sign	2
3-Way Stop Sign	2
4-Way Stop Sign	1
School Zones	4

Appendix C: Criteria for Scoring Road Tests

1. **Vehicle Controls**
    a. Signal
        - Fails to signal a lane change
        - Fails to cancel signal
        - Leaves signal on (when proceeding on a straightaway)
        - Signals through intersection
        - Fails to give an adequate signal to let the driver behind know in sufficient time of their intended lane change
        - Fails to signal when going around any obstruction/vehicles/parked cars in a residential/non-residential area
            - Note: If a participant goes around an obstruction they must signal to go around but are not required when returning to their original lane
            - Note: Participant has to signal when completing a right turn and moving into the second lane because an obstruction/parked vehicle within 100 feet in the extreme right lane after turn

    b. Hand position
        - Hands too high/too low
        - One-handed steering
            - Note: Participant should have two hands on the steering wheel at all times
        - One-handed turning

    c. Other
        - Wipers turned on (unintentionally)
        - Hazard lights turn on (unintentionally)
        - Stalling a vehicle (manual transmission)

2. **Procedural**
    a. Position in lane
        - Straddles traffic line
        - Drives onto the shoulder of the road while on the ramp approaching the highway
        - Wanders (deviates more than 1 metre from a straight line for no apparent reason)
            - Note: Going around parked cars/obstructions is not considered wandering. It becomes a signal violation if no signal is used.
        - Crosses a solid line for no apparent reason
            - Note: This includes crossing a solid bike lane

    b. Stop position
        - Overrunning crosswalk, sidewalk, stop line, or intersection
        - Comes to a stop more than 1 foot into crosswalk, intersection, or over stop line and/or interferes with a pedestrian in the crosswalk

    c. Flow
        - Improper speed (verified by in-vehicle recording device)

- Speed causes the turn to be wide or too fast for proper control
- Turn is too slow
- Hinders traffic

d. Drives in wrong lane
- Has opportunity to change lanes but proceeds in a lane and has to stop because of an obstruction/parked vehicle
- Drives in the left lane and is not overtaking a vehicle
- Does not transition to right lane if possible
- Proceeds straight ahead in a marked turning lane

e. Position on approach
- Fails to turn as closely as practical to the left of centre of the intersection
- Not in the correct position when approaching a turn
- Approaching on the wrong side of the roadway
- Makes turn from improper lane
- Vehicle is not kept within 3 feet of curb/edge of roadway during turn

f. Response to traffic lights
- Travels through intersection on a red light
- Enters intersection on a red light and stops in the first lane of traffic (more than 1 foot over stop line)
- Enters intersection on an amber light and travels through on a red light
- Enters an intersection on a green light and is unable to clear intersection before the light turns red due to stopped traffic

g. Left at light
- Does not enter intersection on first safe opportunity on a green light
- Wheels are not straight

h. Right on red
- Fails to stop while making a right turn on a red light
- Fails to stop at a flashing red light

3. Observations

a. Mirrors:
- Does not check mirrors every 5-8 seconds
  - Note: Only one point will be deducted per segment
- Does not check rear-view mirror while stopping

b. Blind spots (lane changes)
- Does not check blind spot before a lane change
- Checks wrong blind spot before a lane change

c. Blind spots (turning)
- Does not check blind spot before engaging in a turn
- Checks wrong blind spot before engaging in a turn

d. Scan intersections
- Does not look at a perpendicular street when crossing through an intersection

e. Look in direction of movement
- Does not look forward while driving forwards

4. Compliance Error

a. Stops (verified with in-vehicle recording device)
   - Does not come to a complete stop

b. Impedes traffic
   - Does not stop at a safe place
   - Stops too close to another object (e.g., behind stopped vehicles or parked cars)
     - Note: The participant should stop with at least a "3-vehicle" distance between their vehicle and the vehicle in front of them to allow for rear crash avoidance strategies
   - Stops on roadway to wave a pedestrian across who is standing safely at the edge of the road
   - Blocks an intersection or comes to a stop on the wrong side of the street
   - Applies brake for no apparent reason before or after lane changes
   - Slows down while passing through an intersection for no apparent reason
   - Driving slow for no apparent reason/causes a dangerous traffic situation
   - Cuts off vehicle, changes lanes in front of another vehicle causing the other driver to take evasive action
     - Note: If another driver honks at the participant because they cut off the other vehicle, this would signify an error.
   - Hesitates unnecessarily

c. Fails to yield
   - Fails to yield to an emergency vehicle
   - Comes close to a pedestrian or causes interference with a pedestrian who has legally entered the crosswalk zone or is close enough to be in danger
   - Makes no attempt to yield to a pedestrian waiting on the right curb when it appears obvious the pedestrian is attempting to cross the street at the crosswalk
   - Turns into improper lane when turn right and interferes with another vehicle coming from the opposite direction turning left into the same street
   - Turning left causes interference with an oncoming vehicle

d. Fails to clear intersection
   - Enters an intersection and establishes vehicle on a green light, but does not proceed when the way is clear
   - Fails to clear intersection as soon as light turns amber/red

e. Right of way
   - Leaves stop sign when not safe

f. Speeding (verified with in-vehicle recording device)
   - Over the speed limit/speed exception
     - Note: Errors will be scored for every speed exceedance over 5 km/h over the speed limit
     - Note: Use discretion depending on conditions and use regard for actual/potential hazards (e.g., children on/near street, workers, and residential areas with parked cars)
   - Speed constitutes a danger to any person or property

g. Follows too closely
    - Does not allow sufficient distance between their vehicle and the vehicle ahead to stop if necessary
        - Note: Allow for a duration of 3 seconds between the participant and the vehicle directly in front of them

h. Turns
    - Fails to leave intersection to the immediate right of the directional dividing line of the highway or right of center on a residential street being entered
    - Turns into lane with oncoming traffic
    - Vehicle completes turn and drives in any other lane except the extreme right lane

i. Stops without cause
    - Stops for no reason while having the right of way

j. Drives on wrong side of road
    - When not passing parked cars and for no reason drives on the wrong side of a two-way street before or after an intersection//causes a dangerous situation

k. Passing too close
    - Passing too close to pedestrians or vehicles
    - Passing too close to a parked vehicle or a pedestrian, except when necessary
        - Note: Should allow 4-6 feet when passing
    - Passes where unlawful or unsafe
        - Note: Examples include passing on shoulder
    - Passes a moving or stopped vehicle endangering any person or vehicle
    - Passes another vehicle in a school zone or playground with children near
    - Displays no caution when passing in the lane next to a bus loading/unlading passengers
    - Passes a vehicle and drives off roadway
    - Speeds up when being passed

l. Hits curb, hits anything
    - Turn is short and wheel strikes curb
    - Puts wheel over the curb for no apparent reason
    - Hits any object or person

Appendix D: Driving Knowledge Evaluation

Please circle the correct answer:

1. You are approaching a signal when the light suddenly changes from green to yellow. You should:

A. Sound your horn to indicate you are going through
B. Accelerate and clear the intersection as quickly as possible
C. Stop. If stop cannot be made safely, proceed with caution
D. Switch in to the left most lane

2. You and another car stop at a four-way stop at the same time. Right of way goes to:

A. The vehicle furthest into the intersection
B. The vehicle approaching from the right
C. The vehicle approaching from the left
D. Whichever vehicle is able to indicate they are moving in to the intersection first

3. When changing lanes, never change lanes without:

A. Increasing speed and only checking your side mirrors
B. Signalling, checking the rear view mirror and checking blind spots
C. Signalling and decreasing speed
D. You can change lanes at any time without any restrictions

4. Apart from when you are intending to turn left or pass another vehicle on a multi-lane highway you should:

A. Drive in the centre or left lane
B. Drive in the left lane
C. Drive in the right lane
D. Drive in the centre lane

5. As a driver of a vehicle, I am allowed to drive on a bike lane:

A. To pass another vehicle on the shoulder
B. I am not allowed to drive on a designated bike lane
C. On a double-lane street
D. If there are no bikers using the bike lane

6. When performing a left turn, the correct sequence of blind spot checks is to:

A. Look forward, left blind spot check, look forward, and look into turn when proceeding
B. Look forward, left blind spot check, and look into turn when proceeding
C. Left blind spot check, and look into turn when proceeding
D. Look forward, left blind spot check, right blind spot check, and look into turn when proceeding

7. It is important to merge onto a highway in a safe manner. The correct method to merge onto a highway is to:

A. Slowly drive half of the on-ramp
B. Use ¼ of the on-ramp
C. Use most of the on-ramp
D. Stop at the beginning of the on-ramp and wait for vehicles to clear

8. Drivers aged 55 and over, compared with drivers aged 30-54, are involved in:

A. More collisions per kilometre
B. About the same number of collisions per kilometre
C. Less collisions per kilometre
D. It varies each year

Appendix E: Driving Comfort Scales©

Please rate your level of comfort by choosing one option from the scale (0, 25, 50, 75 or 100 %) and writing it beside each situation.

If you do not normally drive in the situation, imagine how comfortable you would be if you absolutely had to go somewhere and found yourself in the situation.

In your ratings, consider confidence in your own abilities and driving skills, as well as the situation itself (including other drivers).

Assume **normal traffic flow** unless otherwise specified.

0%	**25%**	**50%**	**75%**	**100%**
Not at all comfortable		Moderately comfortable		Completely comfortable

'How **comfortable** are you driving in the **daytime**…?'

1. In light rain? _____ %
2. In heavy rain? _____ %
3. In winter conditions (snow, ice)? _____ %
4. If caught in an unexpected or sudden storm? _____ %
5. Making a left hand turn with no lights or stop signs? _____ %
6. Pulling in or backing up from tight spots in parking lots with large vehicles on either side? _____ %
7. Seeing street or exit signs with little warning? _____ %
8. On two-lane highways? _____ %
9. Keeping up with the flow of highway traffic when the flow is over the posted speed limit of 100 km/h (60 miles/h)? _____ %
10. With multiple transport trucks around you? _____ %
11. When other drivers tailgate or drive too close behind you? _____ %
12. When other drivers pass on a non-passing lane? _____ %
13. When other drivers do not signal or seem distracted? _____ %

Now we would like you to rate your level of comfort when driving in the following situations **at night**.

Even if you **do not normally drive at night**, imagine that you were out in the afternoon, got delayed and it was dark on your way back.

In your ratings, consider confidence in your own abilities and driving skills, as well as the situation itself (including other drivers).

Assume **normal traffic flow** unless otherwise specified.

0%	**25%**	**50%**	**75%**	**100%**
Not at all comfortable		Moderately comfortable		Completely comfortable

'How **comfortable** are you driving **at night** …?'

1. In good weather and traffic conditions? _____ %
2. In light rain? _____ %
3. In heavy rain? _____ %
4. In winter conditions (snow, ice)? _____ %
5. When there is glare or reflection from lights? _____ %
6. In unfamiliar routes (different areas), detours or sign changes? _____ %
7. Making a left hand turn with no lights or stop signs? _____ %
8. Pulling in or backing up from tight spots in parking lots with large vehicles on either side? _____ %
9. Seeing street or exit signs with little warning? _____ %
10. On two-lane highways? _____ %
11. Keeping up with the flow of highway traffic when the flow is over the posted speed limit of 100 km/h (60 miles/h)? _____ %
12. With multiple transport trucks around you? _____ %
13. Merging with traffic and changing lanes on the highway? _____ %
14. When other drivers tailgate or drive too close behind you? _____ %
15. When other drivers pass on a non-passing lane? _____ %
16. When other drivers do not signal or seem distracted? ______%

Appendix F: Driving Simulator Feedback

***Provide positive reinforcement during simulation when participants do something correctly.**
***Pause simulation and provide critiques if mistake is made while driving during Session 1.**
***Feedback components: 1) What action they can improve upon.**
2) Why it is important to improve upon this action.
3) How to improve upon this action.

Situation	Feedback
Turning	
Does not signal	1) "You must signal before turning." 2) "Every time there is a choice, you must communicate your intentions so other drivers are aware of what you are doing." 3) "Make sure to indicate whether you are turning left or right before doing so."
Signals too early	1) "You must not signal too early before turning." 2) "If you signal too early, it may look like you are turning somewhere you are not." 3) "Make sure there are no other places your signal could indicate you are turning before you turn it on."
Not in correct lane prior to turning	1) "You must be in the right/left lane before turning right/left." 2) "This constitutes a dangerous act because you are not yielding to other traffic." 3) "Make sure to think further ahead so you can be in the proper lane before turning."
Turns into wrong lane/on to shoulder	1) "You must turn into the correct lane after turning." 2) "This constitutes a dangerous act because you are not yielding to other traffic." 3) "Before turning, find centre line on the road and then start to turn."
Stopping	
Stops too far from traffic light/stop sign	1) "You should not stop too far away from the traffic light/stop sign." 2) "If you stop too far back, others may rear-end you and you will not trigger the sensor." 3) "Make sure to stop right behind the white line."
Stops past traffic light/stop sign	1) "You should not stop past the traffic light/stop sign." 2) "If you stop past the white light, you make not trigger the sensor or you may hit a pedestrian." 3) "Make sure to stop right behind the white line"

Does not scan intersection	1) "You should scan the intersection you are stopped at." 2) "You must do this for your protection so you can see if other cars are coming. 40% of all crashes happen at intersections." 3) "Make sure to scan the intersection before proceeding and watch for cars that are moving, not the ones that are stopped."
Does not come to a complete stop	1) "You must come to a complete stop at a stop sign/light." 2) "This constitutes a dangerous act. Failing to come to a complete stop puts you and others in danger." 3) "Make sure to hold brake until you reach 0 km/h and everything around you has stopped moving."
Stops without cause	1) "You should not stop without a reason to do so." 2) "Stopping without cause makes you unpredictable to other drivers, and puts you at risk of being rear-ended." 3) "Make sure to stop only when there is a reason to do so."
Speeding	
Drives too slow	1) "You should not drive below the speed limit." 2) "Driving too slow impedes traffic, and others might tailgate you putting your safety at risk." 3) "Make sure to drive the speed limit."
Drives too fast	1) "You should not drive above the speed limit." 2) "Driving too fast is unsafe as you may not be able to brake in time if someone cuts in front of you." 3) "Make sure to drive the speed limit."
Decelerates too quickly	1) "You should not decelerate too quickly." 2) "Decelerating too quickly makes you unpredictable to the driver behind you and puts you at risk of being rear-ended." 3) "Do not brake suddenly unless necessary."
Accelerates too quickly	1) "You should not accelerate too quickly." 2) "Accelerating too quickly is especially dangerous in the winter time because spinning tires don't steer in the winter time." 3) "Do not accelerate too quickly."
General	
Incorrect hand positioning	1) "You should not hold your hands too high/too low on the steering wheel."

	2) "Keeping your hands too high on the steering wheel puts you in danger if the air bag were to inflate. Keeping your hands too low on the steering wheel makes it hard to steer and gives you less control." 3) "Keep your hands in the same position as a 10 and 2 would be on a clock."
Crosses line	1) "You cannot cross the center line." 2) "Crossing the centre line constitutes a dangerous act and puts you and others in danger." 3) "Look further down the road (2 blocks) so that you can stay centered in the lane."
Hits a pedestrian/another vehicle	1) "You cannot hit another vehicle or pedestrian." 2) "Hitting another vehicle or pedestrian puts you and others in serious danger." 3) "Beware of your surroundings, especially things that are moving. They should draw your attention more than still things such as lane markings."
Does not check blind spot on lane changes/turns	1) "You must check your blind spot before turning or changing lanes." 2) "Your side mirrors do not always allow you to see what is beside or behind you. Maneuvering without checking your blind spot puts you and others at risk." 3) "Make sure to check your blind spot fully before turning or changing lanes."
Follows too closely	1) "You should not follow too closely behind other vehicles." 2) "If you follow another vehicle too closely, you won't be able to stop in time if they stop. You also will not be able to see in front of the other car." 3) "Stay at least 3 seconds behind the car in front of you."

Appendix G: Demographic Information

Date of birth (dd/mm/yyyy): _ _ / _ _ / _ _ _ _

Sex: [ ] Male [ ] Female

Age when started driving: ___ years

Appendix H: Driving History/Habits Questionnaire

1. Approximately how many **kilometres (miles)** do you drive per week?

[ ] 0-20 km (0-12 miles) [ ] 51-100 km (32-62 miles)
[ ] 21-50 km (13-31 miles) [ ] over 100 km (over 62 miles)

2. When driving, how many accidents (involving a person, car, or fixed object) have you been involved in? (*Do not include cases where you were a passenger*)

 # At fault ________
 # Not at fault ________

3. How long ago was your last **at fault** car accident involving a person, car, or fixed object?

[ ] Less than 1 year [ ] 4-5 years
[ ] 1-2 years [ ] 5-10 years
[ ] 2-3 years [ ] More than 10 years
[ ] 3-4 years [ ] Never had an accident

4. How long ago was your last **not at fault** car accident involving a person, car, or fixed object?

[ ] Less than 1 year [ ] 4-5 years
[ ] 1-2 years [ ] 5-10 years
[ ] 2-3 years [ ] More than 10 years
[ ] 3-4 years [ ] Never had an accident

5. For what purposes do you drive in a **typical week**? *(Check all that apply to you)*
How many times per week?

[ ] Groceries _________
[ ] Other shopping (e.g., drug store, clothes shopping) _________
[ ] Health-related appointments (e.g., doctor, dentist) _________
[ ] Social events (e.g., movie theatre, recreation centres, friends) _________
[ ] Worship (e.g., church, synagogue, etc.) _________
[ ] Hobby-related (e.g., attend classes) _________
[ ] Work, school, or volunteer activities _________
[ ] Family events _________
[ ] Other, please specify _________________________

6. Which driving situation(s) do you find stressful, uncomfortable, or avoid when possible? *(Check all that apply to you):*

[ ] Turning left at intersections [ ] Navigating parking lots
[ ] Driving at night [ ] Changing lanes
[ ] Backing up [ ] Maintaining the speed limit
[ ] Parallel parking [ ] Driving in bad weather

[ ] Driving in unfamiliar areas
[ ] Driving with passengers in the car
[ ] Driving alone
[ ] Driving in heavy traffic
[ ] Other ________________
[ ] None of the above

7. Some people restrict their driving to certain situations. Do you restrict your driving to: *(Check all that apply to you)*

[ ] Daytime
[ ] When accompanied by a passenger
[ ] Outside of rush hour
[ ] Local routes
[ ] Fair weather
[ ] Other _________________________
[ ] None of the above

8. What speed do you typically drive on **local streets** (with a posted speed limit of 50 km/hr)?

[ ] 35 km/hr or less
[ ] 36-45 km/hr
[ ] 46-55 km/hr
[ ] 56-65 km/hr
[ ] 66 km/hr or more

9. What speed do you typically drive on **major highways** (with a posted speed limit of 90 km/hr)?

[ ] 85 km/hr or less
[ ] 86-95 km/hr
[ ] 96-105 km/hr
[ ] 106-115 km/hr
[ ] 116 km/hr or more

Appendix I: Driving History Profile

Instructions:

1. **Please answer all 18 questions to the best of your ability.**
2. **Answer by checking the box or filling in the blank.**

1. How many days a week do you typically drive?

- ◻ 0
- ◻ 1
- ◻ 2
- ◻ 3
- ◻ 4
- ◻ 5
- ◻ 6
- ◻ 7

2. When you drive, who usually rides with you?

(Please check all that apply)

- ◻ Spouse / Partner
- ◻ Family member
- ◻ Friend
- ◻ Caregiver
- ◻ Other
- ◻ No one

3. Has a health condition limited your ability to drive?

- ◻ No
- ◻ Yes

4. Has taking medications limited your ability to drive (over the counter or prescribed)?

- ◻ No
- ◻ Yes

5. Did you get any of the following tested in the last year?

(Please check all that apply)

- ◻ Vision
- ◻ Hearing
- ◻ Physical exam / checkup
- ◻ Other tests (list)_______________________________________

6. In the past year, did you complete any of the following car maintenance? (Please check all that apply)

- ◻ Oil change
- ◻ Checking tires
- ◻ Checking fluid levels
- ◻ Checking headlights, brake lights and parking lights

7. Do you avoid (when possible) any of these driving situations? (Please check all that apply)

- ◻ Rush hour/heavy traffic
- ◻ Interstate/ highway driving
- ◻ Rain
- ◻ Night-time driving
- ◻ Left hand turns against traffic
- ◻ Other (list)____
- ◻ None

8. Do you use alternative transportation (such as taking a bus or taxi)?

- ◻ Always
- ◻ Often
- ◻ Sometimes
- ◻ Rarely
- ◻ Never

9. Would you consider alternative transportation if it were available?

- ◻ No
- ◻ Yes

10. As the driver on a long trip, how frequently do you take breaks?

- ◻ Every 1 to 2 hours
- ◻ Every 3 to 4 hours
- ◻ Every 5 to 6 hours
- ◻ Rarely or Never

11. Is it difficult for you to fasten your seatbelt?

- ◻ Always
- ◻ Often
- ◻ Sometimes
- ◻ Rarely
- ◻ Never

12. As a driver, have you been involved in a crash in the past 3 years? (If you mark "No", go to question #14

- ◻ No
- ◻ Yes

13. As a driver, how many crashes were you involved in during the past 3 years?

- ◻ 1
- ◻ 2
- ◻ 3
- ◻ 4
- ◻ 5 or more

14. How many moving violations, citations or traffic tickets have you had in the past 3 years? (If you mark "0", go to question #16)

- ◻ 0
- ◻ 1
- ◻ 2
- ◻ 3
- ◻ 4
- ◻ 5 or more

15. What moving violations, citations or traffic tickets did you receive in the past three years? (Please check all that apply)

- ◻ Failure to yield
- ◻ Going too slowly
- ◻ Not obeying traffic lights
- ◻ Not obeying traffic signs (such as stop sign)
- ◻ Improper passing
- ◻ Improper turning
- ◻ Careless driving
- ◻ Reckless driving
- ◻ Driving under influence of drugs or alcohol (DUI/DWI)
- ◻ Speeding
- ◻ Tailgating
- ◻ Other (list)______________________ ________________

16. When did you last attend a driver education, training or retraining course? (If you mark "Never", go to question #18)

- ◻ Within the past year
- ◻ 1 – 3 years ago
- ◻ More than 3 years ago
- ◻ Never

17. If you have attended a driver education class, training or re-training, what type was it? (Please check all that apply)

- ◻ On-line class
- ◻ Classroom course for all drivers
- ◻ Classroom course for mature drivers
- ◻ Course with classroom and behind the wheel instruction
- ◻ Other (list)____________________________________

18. How do you keep up with changes in road rules or laws?

(Please check all that apply)

- ◻ Driving class
- ◻ Newspaper
- ◻ TV
- ◻ Driver’s handbook
- ◻ Friends or family
- ◻ Computer
- ◻ Police or law enforcement
- ◻ Driver’s license office (DMV)
- ◻ Other (list)_____________________________________
- ◻ None of the above

Appendix J: SPSS Output for Sample Size Calculations

```
*Y = on-road evaluation
  Y0 = baseline value
  Y1 = post-intervention value
 X = intervention with 3 groups
  1 = control (BT group)
  2 = BT+OR group
  3 = BT+OR+S group

*Expected pattern of results:
Control: no change
BT+OR group: 10% improvement from baseline
BT+OR+S group: 20% improvement from baseline

*Baseline mean from subsample of population: Mean=100, SD=15.

*Analysis options
1. ANCOVA with Y0 as covariate
2. Multilevel model

*-----------------------------------------------------------.
*The following syntax reads in these data in matrix format.
*-----------------------------------------------------------.
New file.
Dataset close all.
Matrix data
      Variables = group rowtype_post pre
      /factor = group
      /format = lower nodiagonal.
Begin data.
1 mean 100 100
1 n 25 25
2 mean 100 90
2 n 25 25
3 mean 100 80
3 n 25 25
. sd 15 15
. corr 0.8
End data.

* Exclude control group for now, contrast between BT+OR and BT+OR+S
only.
Manova
 Post by group (2,3) with pre
 /method = unique
 /error = within+residual
 /matrix = in(*)
 /power t (.05) F (.05)
 /print signif (mult averf)
 /noprint param(estim).
```

```
*******************Analysis of Variance*****************************
50 cases accepted.
0 cases rejected because of out-of-range factor values.
0 cases rejected because of missing data.
2 non-empty cells.

1 design will be processed.


----------------------------------------------------------------------

Tests of Significance for post using UNIQUE sums of squares

Source of Variation        SS    DF    MS         F     Sig of F
WITHIN+RESIDUAL       3888.00    47    82.72
REGRESSION            6912.0     1     6912.0     83.56      .000
GROUP                 717.01     1     717.01     8.67       .005
----------------------------------------------------------------------

Observed Power at the .0500 Level

Source of Variation   Noncentrality   Power

Regression            83.55556        1.000
Group                 8.66759         .820

----------------------------------------------------------------------

*Now include BT group.
Manova
 Post by group (1,3) with pre
 /method = unique
 /error = within+residual
 /matrix = in(*)
 /power t (.05) F (.05)
 /print signif (mult averf)
 /noprint param(estim).


*******************Analysis of Variance*****************************
75 cases accepted.
0 cases rejected because of out-of-range factor values.
0 cases rejected because of missing data.
2 non-empty cells.

1 design will be processed.


----------------------------------------------------------------------
```

Tests of Significance for post using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	5832.00	71	82.14		
REGRESSION	10368.0	1	10368.0	126.22	.000
GROUP	2445.28	1	1222.64	14.88	.000

Observed Power at the .0500 Level

Source of Variation	Noncentrality	Power
Regression	126.22222	1.000
Group	29.76939	.999