REFRESHING OLDER ADULTS' DRIVING SKILLS

ROADSKILLS:

DEVELOPING AN EVIDENCE-BASED AND USER-INFORMED APPROACH

TO REFRESHING OLDER ADULTS' DRIVING SKILLS

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Lay Abstract

Being able to drive is important to many older Canadians. Unfortunately, drivers aged 70+ have a high risk of being injured or killed in a car crash. Many crashes could be avoided by improving their driving skills. This thesis describes the development of an older driver training program. The first study examined research evidence on such programs where tailoring feedback was key to improving on-road performance. In the second study, older adults and other stakeholders identified what was important when designing training for aging drivers. They felt the focus should be on areas of improvement as well as strengths when behind-the-wheel. In the final study, older drivers underwent training where they watched either a video with feedback on their driving or a generic video on aging-in-place. Those who received feedback made fewer mistakes behind-the-wheel. Findings emphasize the importance of including older adults' needs and preferences when designing driver training programs.

Abstract

Driving is the preferred mode of transportation among community-dwelling older Canadians. Unfortunately, drivers aged 70+ have a high risk of being injured or killed in a collision. Many collisions are caused by poor driving habits, which could be avoided by improving their behind-the-wheel behaviours. The manuscripts in this thesis describe the development of an evidence-based and user-informed driver training program aimed at refreshing older adults' driving skills.

First, a systematic review of older driver training programs was undertaken to examine evidence specific to the impact of this training on improving road safety knowledge, self-perceived driving abilities, and on-road performance. Results highlighted the breadth of approaches used to train older drivers. Interventions were most effective when feedback was tailored to the specific needs of an aging driver.

The second manuscript outlines a qualitative descriptive analysis exploring older adults' motivations to participate in driver training with key stakeholders (i.e., older drivers and service delivery providers). Findings indicated having insight into one's driving abilities, experiencing a near-miss or crash, as well as an openness to improving behind-the-wheel skills were factors that could influence seeking out and participating in such training. Stakeholders also emphasized considerations for educating older drivers.

The final manuscript describes the design and evaluation of a driver training program. In this randomized controlled trial, older drivers watched either a video of tailored feedback on their driving or a generic video on aging-in-place. When the on-road

performance was compared between treatment groups, those who received tailored feedback significantly reduced the number of errors they made behind-the-wheel.

Ensuring driver training programs are designed to consider the specific needs and preferences of older adults is critical, which can lead to innovations that help maintain driving ability and community mobility in later life.

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List of Abbreviations and Symbols

Abbreviations

ACTIVE –	Advanced Cognitive Training for Independent and Vital Elderly
ADAS –	advanced driver assistance systems
ADLs –	activities of daily living
AMED –	Allied and Complementary Medicine
CAOT –	Canadian Association of Occupational Therapists
CDE –	comprehensive driving evaluation
CG –	control group
CI –	confidence interval
CINAHL –	Cumulative Index to Nursing and Allied Health Literature
CMAJ –	Canadian Medical Association Journal
CONSORT –	Consolidated Standards of Reporting Trials
DBQ –	Driving Behaviour Questionnaire
DCS –	Driving Comfort Scale
DEC –	Driving as an Everyday Competence
DHQ –	Driving Habits Questionnaire
DI –	driving instructor
DPPQ –	Driving Perception and Practice Questionnaire
EMBASE –	Excerpta Medica database
ERIC –	Education Resources Information Centre

GDE –	Goals for Driver Education
GDE5SOC –	Goals for Driver Education in the Social Perspective
GES –	Group Education Session
GPS –	Global Positioning System
GRIPP2 –	Guidance for Reporting Involvement of Patients and the Public
HBM –	Health Belief Model
HiREB –	Hamilton integrated Research Ethics Board
ICC –	Intraclass correlation coefficient
IG –	intervention group
MTO –	Ontario Ministry of Transportation
MVC –	motor vehicle collision
N/A –	not applicable
n –	number
OR –	odds ratio
OT –	occupational therapist
PAPM –	Precaution Adoption Process Model
PEO –	Person Environment Occupation
PDA	Perceived Driving Abilities
PRISMA –	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO –	Prospective Register of Systematic Reviews
RCT –	randomized controlled trial

RoB –	Risk of Bias
ROBINS-I –	Risk Of Bias In Non-randomized Studies – of Interventions
SCT –	Social Cognitive Theory
SD –	standard deviation
SDA –	Situational Driving Avoidance
SDF –	Situational Driving Frequency
SEM –	standard error of measurement
SOC –	Selection, Optimization and Compensation
SRT –	Self-Regulation Theory
SKILL –	Staying Keen in Later Life
TIDieR –	Template for Intervention Description and Replication
TTM –	Transtheoretical Model of Behaviour Change
WHO –	World Health Organization

Symbols

\> – greater than

< – less than

≥ – greater than or equal to

\+ – plus

α – alpha

κ – kappa

± – plus/minus

® – registered

© – copyright

Declaration of Academic Achievement

This doctoral dissertation is presented as a manuscript-style ("sandwich") thesis consisting of three independent but related research studies (Chapters 2-4). Ruheena Sangrar made significant and original contributions to all studies in this thesis and is the first author on all three manuscripts. At the time this thesis was prepared, Chapter 2 was published and Chapters 3 and 4 were drafted for submission to peer-reviewed journals. Author contributions made by the candidate (Ruheena Sangrar) are outlined below:

Chapter #2: Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance

Ruheena Sangrar, with the guidance of Dr. Brenda Vrkljan, conceptualized the purpose and research question for this review. She developed the systematic review protocol with input from Drs. Brenda Vrkljan, Lori Letts and Lauren Griffith. Ruheena Sangrar conducted all data collection with assistance from Joon Mun and Michael Cammarata as second reviewers. She led the data analysis and interpretation with assistance from Dr. Brenda Vrkljan. The manuscript was prepared by Ruheena Sangrar, guided by Dr. Brenda Vrkljan, and editorial assistance and feedback from all co-authors.

Chapter #3: Older adults' motivations for participating in a 'tune-up' of their driving skills: A multi-stakeholder analysis

Ruheena Sangrar, with the guidance of Dr. Brenda Vrkljan, conceptualized the purpose, research question, and study design of this qualitative study, with input from Drs. Lori Letts and Lauren Griffith. Drs. Brenda Vrkljan and Lori Letts assisted with participant recruitment. Ruheena Sangrar led the data collection (focus groups and interviews) with guidance from Dr. Vrkljan and administrative assistance from Joon Mun. She led the data analysis with guidance from Dr. Vrkljan and assistance from Joon Mun as a second coder. The manuscript was prepared by Ruheena Sangrar, with guidance from Dr. Brenda Vrkljan and editorial assistance and feedback from all co-authors.

Chapter #4: Refreshing Older Adults' Driving Skills (ROADSkills): A randomized controlled trial examining the effect of video feedback

Ruheena Sangrar, with the guidance of Dr. Brenda Vrkljan, conceptualized the purpose and research question for this randomized controlled trial. She developed the study design and protocol with input from Drs. Brenda Vrkljan, Lori Letts, Lauren Griffith and Michelle Porter. Ruheena Sangrar led all data collection (baseline assessments, intervention delivery, and follow-up), data analysis and interpretation. She received assistance with recruitment from Dr. Brenda Vrkljan and statistical analyses from Drs. Lauren Griffith and Jinhui Ma. The manuscript was prepared by Ruheena Sangrar, with guidance from Dr. Brenda Vrkljan and editorial assistance and feedback from all co-authors.

Chapter One: Introduction

Background

For many older adults, having access to safe and reliable transportation is necessary to their engagement in out-of-home occupations. Ninety-two percent of Canadians aged 65 years and older reside in private households (Statistics Canada, 2012), many of which are within neighbourhoods designed around the automobile, which have been referred to as “Auto Suburbs” (Gordon & Shirokoff, 2014). In Canada, similar to many other Western nations, having a driver’s license in later life is often equated with freedom and independence. However, as we grow older, we are more likely to experience age and health-related changes that can impact our behind-the-wheel performance. Without viable transportation alternatives, reduced mobility, including loss of licensure, has been linked to depression in older adults (Chihuri et al., 2016; Fonda, Wallace, & Herzog, 2001; Ragland, Satariano, & MacLeod, 2005; Windsor, Anstey, Butterworth, Luszcz, & Andrews, 2007). Until appropriate public transportation and other alternatives are readily available, older drivers will want and need to drive. Hence, developing interventions that keep them safe behind-the-wheel for as long as possible is necessary.

Almost 10 years ago, a joint editorial published in the Canadian Medical Association Journal (CMAJ), implored physicians and other health professionals to create “programs to help seniors drive safely for as long as possible and, when they can’t, to help them get around” (MacDonald & Hébert, 2010, p. 645). In keeping with emerging research that suggests providing older adults with training from a driving instructor can improve their behind-the-wheel behaviours (e.g., Anstey, Eramudugolla, Kiely, & Price, 2018; Gagnon et al., 2019; Sawula et al., 2018), there is a pressing need to develop interventions aimed at improving driving skills in later life (Dickerson et al., 2017). Building on the most recent evidence, this doctoral dissertation focuses on the design and evaluation of an innovative approach to refresh the behind-the-wheel skills of older drivers. The information in this introductory chapter provides the context and rationale for the research studies undertaken in this thesis.

The overall objectives of this dissertation, as well as a brief summary of each included manuscript, are outlined in the sections that follow. As a manuscript-style ('sandwich') thesis, Chapters 2, 3, and 4 describe distinct, yet inter-related, research studies that each synthesize evidence specific to the impact of training on older drivers. These chapters have been formatted in accordance with the requirements for the peer-reviewed journals to which each have or will be submitted. The final chapter of this dissertation consolidates evidence from these studies and discusses the potential implications of this research for both policy and clinical practice.

Aging-in-Place: The importance of community mobility and driving

Being able to live where one chooses and engage in out-of-home occupations can help individuals feel connected to their community in later life (Canadian Association of Occupational Therapists [CAOT], 2019; Löfqvist et al., 2013; Vrkljan, Leuty, & Law, 2011; Wiles, Leibing, Guberman, Reeve, & Allen, 2012). Supporting older adults to age-in-place has been found to have many socioeconomic benefits, such as lowering rates of admission to acute care and institutionalization (Thomas & Blanchard, 2009; U.S. Department of Housing and Urban Development, 2013). Older adults are also recognized as major contributors to the social capital of their communities, as they take on many roles, such as providing childcare and/or volunteering (Iecovich, 2014; Pace & Grenier, 2017; Ranzijn, 2002; Thomas & Blanchard, 2009). Access to transportation is often necessary to engage in these valued roles.

Community mobility has been defined as “planning and moving around in the community and using public or private transportation, such as driving, walking, bicycling, or accessing and riding buses, taxi cabs, or other transportation systems” (American Occupational Therapy Association, 2014, p. S19). The International Classification of Functioning, Disability and Health (ICF) (World Health Organization [WHO], 2002) frames the ‘use of transportation’ and ‘driving’ as distinct entities under the larger construct of ‘mobility.’ Within the ICF, mobility is defined as “moving by changing body position or location or by transferring from one place to another, by carrying, moving or manipulating objects, by walking, running or climbing, and by using various forms of transportation” (WHO, 2001, p. 142). While the ability to move around one’s home and community is seen as integral to health and everyday functioning in later life (Metz, 2000; Rantakokko et al., 2016), mobility can be impacted by a multitude of factors, including financial, psychosocial, environmental, physical, and cognitive issues, as well as demographic considerations (e.g., gender) (Webber, Porter, & Menec, 2010). For example, the sudden onset of a medical condition in later life, such as a stroke, can impact the physical and cognitive functions needed to be able to walk and drive. Hence, the ensuing loss of mobility can lead to barriers in accessing one’s community and, in turn, restrict participation (WHO, 2001).

Not being able to drive has also been associated with a downward spiral in older adults' health and social functioning (Freeman, Gange, Muñoz, & West, 2006). Using weighted data from interviews and follow-up surveys with over 4500 adults aged 70 years and older, Foley and his colleagues (2002) prognosticated that most seniors will outlive their driving ability by at least 7 years. The Canadian National Senior's Council (2014) also identified loss of licensure as a major risk factor for social isolation. Loss of driving ability in older adulthood has been linked to the onset of depressive symptoms (Chihuri et al., 2016; Fonda et al., 2001; Ragland et al., 2005; Windsor et al., 2007). Evidence suggests that when older adults give up their license whether it be voluntarily or otherwise, they are more like to transition to long term care, especially if they live alone (Freeman et al., 2006). The onset and accumulation of health impairments can also increase the crash risk of older drivers, which poses a major public safety issue for all road users.

Older adults' involvement in motor vehicle collisions

For all road users, motor vehicle collisions (MVCs) are a pressing public health concern. Globally, an estimated 1.3 million deaths and 78.2 million injuries are attributed to MVCs every year (Global Road Safety Facility, 2014). In 2017 alone, 1,841 Canadians drivers were killed in an MVC of which 18% were aged 65 years and older (Transport Canada, 2019). Fatality rates in older drivers are disproportionately higher when compared to the broader driving population (Naumann, Dellinger, Zaloshnja, Lawrence, & Miller, 2010; Vanlaar et al., 2016). Although MVC-related fatalities among this age group have decreased over the past decade in both Canada and the United States (Cheung & McCartt, 2011), these reductions have been attributed, in part, to safety-related innovations in vehicle design. However, even with such innovations, the odds of being involved in a fatal collision are still 2.9 times higher for drivers aged 70+ and 4.2 times higher for those aged 80+ than that of middle-aged drivers (i.e., 35-54 years) (Cheung & McCartt, 2011). Unfortunately, there is limited evidence describing the proportion of older adults who had a medical condition that resulted in an MVC.

Recent studies examining crash rates among seniors suggest it may be a particular subset of the older driver population who have a higher risk of collisions. The term 'low mileage bias' (i.e., a metric of driving exposure), has been used to describe those seniors who drive fewer miles annually (Antin et al., 2017; Hakamies-Blomqvist, Raitanen, & O'Neill, 2002; Langford, Methorst, & Hakamies-Blomqvist, 2006). Further analysis by Antin and colleagues (2017) found drivers aged 75 – 99 years, particularly those who are female and/or drive fewer than 3000 miles annually, have the highest crash risk. Many hypothesize their elevated crash risk might be due, in part, to living in more urban areas where older adults drive shorter distances but in more complex traffic environments that increase their likelihood of collision (Antin et al., 2017; Hakamies-Blomqvist et al., 2002; Janke, 1991; Langford et al., 2013, 2006; Regev, Rolison, & Moutari, 2018). Most recently, Regev and colleagues (2018) suggested the relationship between driving exposure and MVC-risk in older adulthood is not linear, rather crash rates plateau, as distance driven increases. While their analyses indicated crash rates of older drivers might actually be lower than previously reported, they found MVC-related fatalities remained higher for this population. Interestingly, compared to younger cohorts who are more likely to be killed in crashes at night, MVC fatality rates for drivers 70 years and older remained consistent across time of day (Regev et al., 2018).

A growing body of evidence has also examined the types of crashes in which older drivers are involved. Their collisions have been found to occur under more cognitively demanding situations, such as turning left at intersections, when merging, or making a lane changes (Cicchino & McCartt, 2015; Davis, Casteel, Hamann, & Peek-Asa, 2018; Koppel, Bohensky, Langford, & Taranto, 2011; Vichitvanichphong, Talaei-Khoei, Kerr, & Ghapanchi, 2015). A closer examination of this evidence further indicated many of these collisions may, in fact, be avoidable. Examples of remediable errors among older drivers include, but are not limited to: inadequate surveillance of the roadway, gap or speed misjudgement, poor vehicle control, issues with managing their speed, and lack of compliance with traffic safety regulations (Cicchino & McCartt, 2015; Davis et al., 2018; Koppel et al., 2011; Vichitvanichphong et al., 2015). Hence, there is an opportunity to consider how we might best address the needs of older drivers through evidence-based interventions designed to optimize their behind-the-wheel performance.

Raising the issue of driving with older adults in a healthcare context

Healthcare professionals are often the first to recognize when medical changes might impact one's fitness-to-drive (Dickerson, Schold Davis, & Carr, 2018; Henderson et al., 2015). In Ontario, as with many other jurisdictions in North America, healthcare professionals have a legal and professional obligation to report drivers to the transportation authority if they suspect a medical condition could impact a person's behind-the-wheel abilities. For example, the Ontario Ministry of Transportation (MTO) has legislation in place that require certain healthcare professionals, including physicians, optometrists and nurse practitioners, to report such drivers (MTO, 2019). Occupational therapists (OTs) are the most recent profession to be afforded the discretionary authority to report clients with functional impairments that could impair their ability to operate a motor vehicle (MTO, 2019). Assessing an individual's medical fitness-to-drive, along with maintaining and/or restoring driving-related abilities, is considered within the scope of occupational therapy practice in Canada (CAOT, 2009).

In their clinical roles, OTs assess older adults' everyday functional abilities in both community and hospital-based contexts. Potential concerns with driving ability that are identified are classified as an occupational performance issue which informs assessment and intervention planning. For example, an older client who has a stroke can experience physical and cognitive impairments that require a more in-depth assessment of their driving abilities. Such an assessment is referred to as a comprehensive driving evaluation (CDE). CDEs are usually conducted by OTs who have extra training to examine medical fitness-to-drive in collaboration with trained driving instructors. Alternatively, OTs that practice as generalists in primary care settings may determine this client does not have the capacity to operate a motor vehicle and would subsequently submit a medical report to the MTO, advising the client of their decision.

In their frontline clinical work with older adults, OTs are trained to consider how their clients access out-of-home activities and, in turn, if their behind-the-wheel abilities might be affected by the presenting medical condition and/or changes in the environment (Zur & Vrkljan, 2014). As such, OTs are well-positioned to initiate a conversation about an older adult's perceived changes in driving behaviours and/or or their ability to access alternative transportation options beyond the personal automobile (CAOT, 2019). OTs can then collaborate with the individual to develop strategies for enabling out-of-home mobility. However, given the sensitivity of discussing driving capacity in later life, raising this topic can be challenging for OTs. These conversations are especially difficult if an older adult has not thought about how they will get around their community when driving is no longer an option (CAOT, 2009; Sangrar, Griffith, Letts, & Vrkljan, 2018). As such, interventions that consider the perspectives of older adults who may not yet be experiencing deficits that impact their behind-the-wheel abilities are warranted. By understanding and integrating the perspectives of this segment of aging drivers, programs can be designed to better address their needs and preferences. The following section outlines conceptual frameworks that describe how behind-the-wheel abilities can change in later life and considerations for designing driver training programs aimed at supporting the community mobility of our aging population.

Theoretical considerations for driver training in older adulthood

The Person-Environment-Occupation Model and driving in later life

For many older adults, driving can be considered an instrumental activity of daily living (iADL) that is an occupation in and of itself (Dickerson, Reistetter, Schold Davis & Monahan, 2011). Driving is a dynamic activity that requires sensory-perceptual, cognitive-, and psychomotor-based tasks, which can decline with age (Mazer, Gelinas, & Benoit, 2004). To perform an activity like driving, the requirements of each task (e.g., vehicle operation, route planning, etc.), elements of the environment, alongside an individual's capacity to perform the occupation in question must be considered. The Person, Environment, Occupation (PEO) Model highlights how various factors integrate to influence an individual's ability to engage in an occupational role, or their 'occupational performance' (Law et al., 1996). Within the PEO, occupational factors are a compilation of purposeful, functional tasks and activities. Occupational performance can be influenced by personal factors, such as one's learned and innate skills, characteristics, and life experiences. Cultural, socio-economic, institutional, physical and social factors are elements of the environment within which an occupation is conducted (Law et al., 1996). Using the PEO model, an older adult's behind-the-wheel performance is considered a transactional process where the elements of the driving environment and the current skills and abilities of the person in question come together to enable engagement in the driving activity. Hence, any training or other approaches aimed at improving the behind-the-wheel performance of older adults must consider this dynamic transaction and how person, environment, and occupation factors might be addressed through driver training in later life.

The Driving as an Everyday Competence Model

In his examination of various approaches to driver training, Shinar (2017) differentiated between the constructs of *driver performance* and *driver behaviour*. *Driver performance* was defined as “the best a driver can do in a typical situation,” whereas *driver behaviour* referred to “what a driver tends to do in the typical situation, within his or her limits of performance” (p. 89). Driver training approaches optimize an individual’s abilities with the aim of decreasing any disparity between what they have the capacity to do and what they actually do. Shinar’s (2017) definition of *driver performance*, is similar to the notion of *competence* used by Lindstrom-Forneri and colleagues (2010) in their ‘Driving as an Everyday Competence (DEC) Model’ (see **Figure 1**) in terms of describing an individual’s capacity to operate a motor vehicle.

The DEC Model builds on a framework of driving, first conceptualized by Michon (1985). The ‘Michon Model’ describes a hierarchy of decision-making when it comes to the task of driving. This hierarchy suggests three levels of cognitive control: 1) operational (i.e., the execution of conscious or automatic actions required to manipulate the vehicle); 2) tactical (i.e., maneuvering the vehicle within the immediate environment); and 3) strategic (i.e., high-level decisions made about trip path and route). The DEC Model takes the Michon Model a step further by considering the transactional relationship between individual factors, including cognitive control with that of contextual elements, which are then moderated by a driver’s beliefs, attitudes and self-awareness. A particular strength of the DEC Model is its naming and framing of factors that can impact a driver's sense of competence in later life, including the importance of self-perceptions in one's driving abilities as well as societal attitudes towards driving. The DEC Model highlights how such elements can impact strategic decisions about if, where, and when one drives, such as not driving at night, on highways, or other self-regulatory strategies that are common among older drivers.

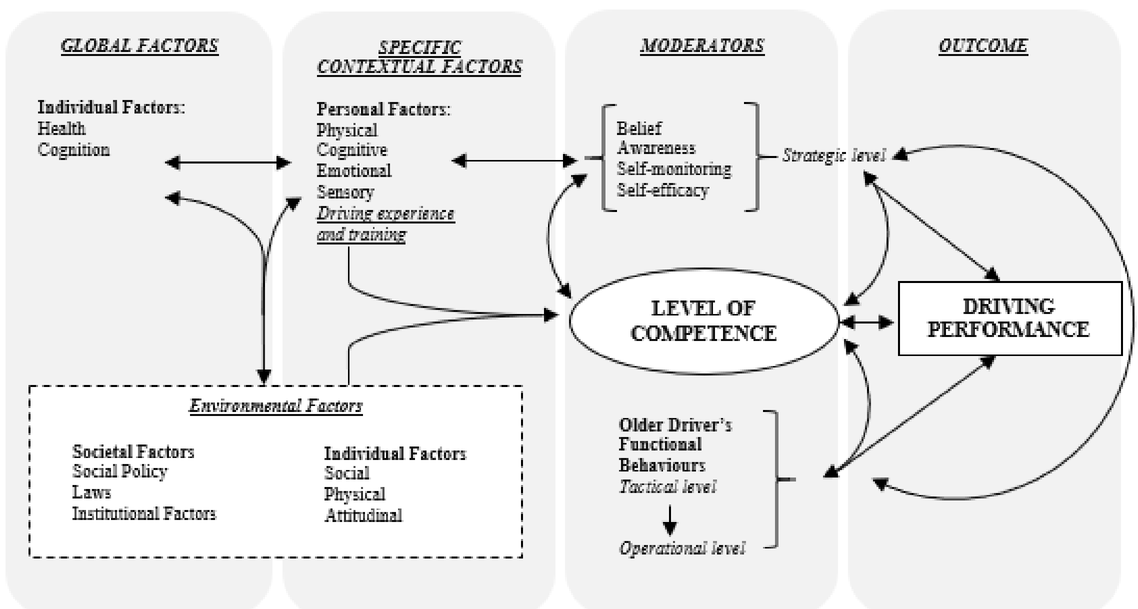

Figure 1 Driving as an Everyday Competence (DEC) Model as it applies to driver training aimed at older driver's functional behaviours (Adapted from Lindstrom-Forneri et al., 2010).

The DEC Model also includes *global factors*, which refer to higher-level areas that can impact crash risk, such as how legislation and regulations (e.g., traffic laws and license renewal procedures) alongside institutional factors (e.g., alternative transportation or health services) can impact community access and mobility. An older adult's functional capacity to operate a vehicle is thought to be influenced by both broader *individual factors* (i.e., those associated with their age cohort/ health population), as well as *personal factors* (i.e., unique to the person in question). To further elaborate on this set of factors, the DEC Model draws on the Multifactorial Model of Driving Safety (Anstey, Wood, Lord, & Walker, 2005). The Multifactorial Model of Driving Safety consolidates research evidence examining the association between driving competence (i.e., on-road performance, crash rates, self-report) and functional abilities. Examples of functional abilities associated with driving competence included in this model are cognitive abilities (e.g., reaction time, speed of processing, visual attention, short-term memory, and executive function), vision (e.g., acuity and contrast sensitivity), and physical function (e.g., history of falls, neck rotation, presence of chronic diseases such as arthritis and heart disease). According to the Multifactorial Model of Driving Safety, these functional abilities determine an individual's driving capacity, or the best one can perform when behind-the-wheel, synonymous with *level of competence* in the DEC Model (see **Figure 2**). While the DEC Model has been criticized for borrowing from existing models (e.g., Michon Model, Multifactorial Model of Driving Safety) rather than using research evidence to inform the naming and framing of key factors (Wong, Smith, Sullivan, & Allan, 2016), it provides a comprehensive overview of the potential relationships across a range of variables that might be amenable to change through targeted training of one's behind-the-wheel abilities.

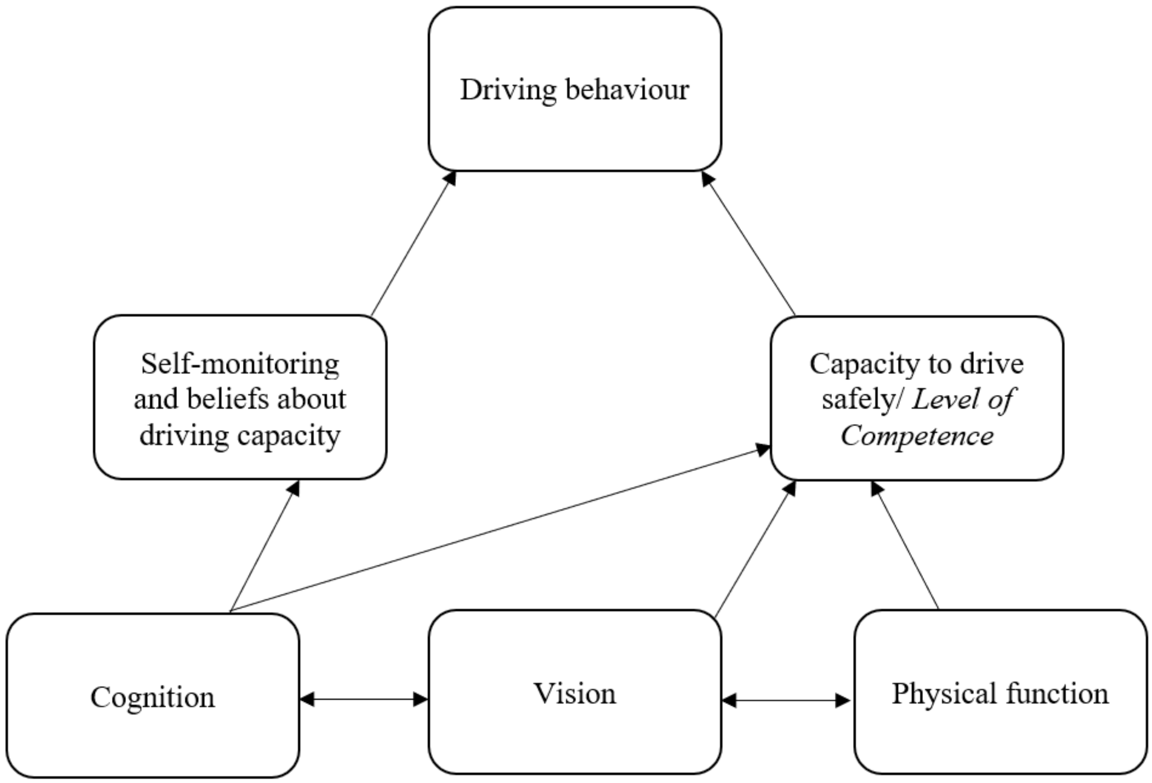

Figure 2 Multifactorial Model of Driving Safety as it relates to the 'Level of Competence' construct in the DEC Model (Adapted from Anstey et al., 2005).

Goals for Driver Education in the Social Perspective

To date, most training approaches have been designed for novice drivers. In 2014, Keskinen (2014) identified how a framework used to inform novice driver education, the Goals for Driver Education (GDE) (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002) could be adapted to incorporate key principles for improving the driving skills of older adults. This new framework was called the Goals for Driver Education in the Social Perspective (GDE5SOC) (see **Figure 3**). A unique feature of GDE was its integration of the hierarchical levels of the Michon Model in terms of how the goals for driver education were framed. By framing the goals in a hierarchical model, they hold much potential for informing the design and development of new approaches for older driver training. These goals include four main levels: 1) Vehicle maneuvering (e.g., controlling the speed and direction of the automobile); 2) Mastering traffic situations (e.g., responding to stimuli and demands of a driving maneuver); 3) Goals and context of driving (e.g., route planning and travelling with passengers); and 4) Goals for life and skills for living (e.g., one's identity as a driver, lifestyle and living arrangements dependent on access to a personal vehicle) (Hatakka et al., 2002). For older adults, their desire to age-in-place could be classified as a goal at the fourth level.

In his discussion of this framework, Keskinen (2014) highlighted the potential influence of a fifth and final level, the social environment, on driver training. At this level, contextual influences on driving and community mobility, such as licensing regulations, cultural norms and values, are recognized as influencing one's motivation to undertake driver education in later life. According to Keskinen (2014), older driver training aimed at improving behind-the-wheel performance (i.e., at the lowest levels of the GDE5SOC Framework) should be direct and specific with the aim of enhancing knowledge and skills. Older learners should be encouraged towards ongoing self-evaluation of their abilities at this life stage. Hence, it is critical that education aimed at older drivers be congruent with not only their goals for improving their driving, but also the needs of older learners to whom such training is targeted.

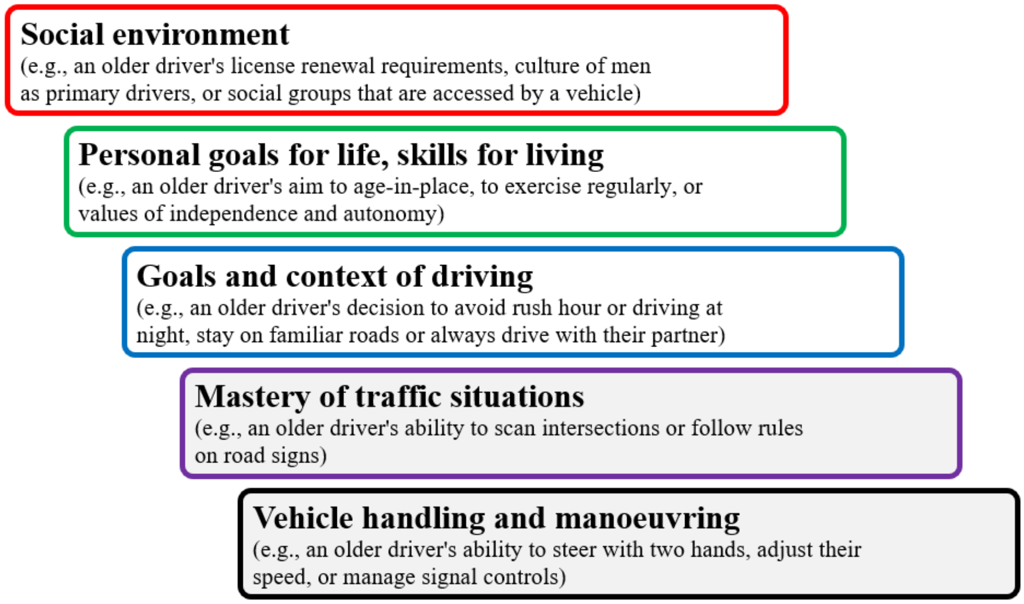

Figure 3 Driving hierarchy that informs Goals for Driver Education in the Social Perspective (GDE5SOC) with examples of how it relates to Older Drivers' Functional Behaviours, Specific Contextual Factors and Global Factors in the DEC Model (Adapted from Keskinen, 2014).

Statement of the Problem

To date, much research on older drivers has focused on determining assessment protocols to identify those who present a medical risk when behind-the-wheel. While these individuals pose a significant concern to public safety, there remains a growing segment of older drivers that have not yet experienced medical changes that can impact their driving, but who might still benefit from training (Antin et al., 2017; National Highway Traffic Safety Administration, 2017). For these individuals, there is an opportunity to develop training approaches that can improve their behind-the-wheel abilities. However, an ongoing challenge in the field of driver training and rehabilitation research is the dearth of evidence that demonstrates the effectiveness of such approaches. Previous systematic reviews of older driver training programs (Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009; Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, 2007) have not examined this evidence in terms of their effect on key outcomes, namely road safety knowledge, self-perceptions of behind-the-wheel abilities, and objective measures of driving performance, such as crashes. It is also important to consider the perspectives of older adults to whom such programs are targeted, as well as those of other stakeholders who might recommend or even deliver the training in question (e.g., driving instructors, OTs). By combining the best research evidence with the perspectives of actual users, the ultimate goal of this doctoral dissertation was to identify and address existing gaps in knowledge on older driver training aimed at refreshing the behind-the-wheel skills of our aging population.

Thesis objectives: An overview of included studies

This dissertation examined the most up-to-date evidence on programs aimed at refreshing the driving skills and abilities of older adults, while also considering user perspectives, with the ultimate **aim** of developing and evaluating a novel older driver training program. The evidence-based rehabilitation process, as described by Law and MacDermid (2013), informed the integrated approach undertaken in the design and evaluation of the *Refreshing Older Adults' Driving Skills* (ROADSkills) program. ROADSkills consolidates the most current research on older driver training with the values and preferences of older drivers as well as those of other stakeholders who might recommend (e.g., clinicians) or administer (e.g., driving instructors) such training (see **Figure 4**). A sequential exploratory mixed-methods design strategy guided this program of research and its corresponding objectives (Creswell & Plano Clark, 2018). The main objectives of this thesis were as follows:

1. To identify the most effective **training approaches** for improving older adults' driving performance (Chapter 2).
2. To determine factors that can impact older adults' **engagement in driver training** from the perspective of older drivers, driving instructors, and clinicians (Chapter 3).
3. To **design an older driver training program** based on the best evidence and with input from key stakeholders, including seniors, driving instructors and clinicians (Chapter 4).
4. To evaluate the **effectiveness of this program** on both subjective and objective outcomes assessing the behind-the-wheel performance of older drivers (Chapter 4).

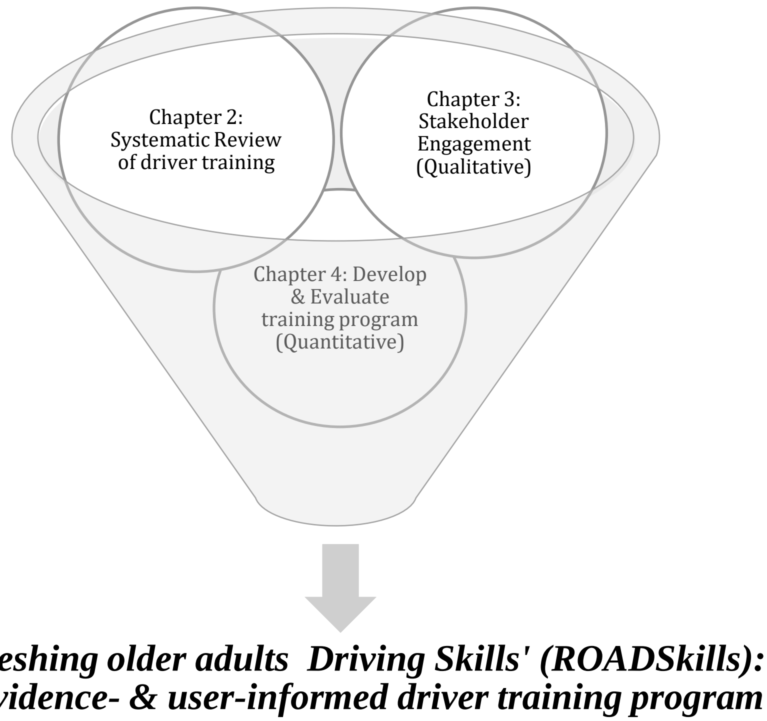

Figure 4 Sequential exploratory mixed-methods strategy used to guide an evidence- and user-informed program of research aimed at older driver training.

A short overview of each study in this thesis is provided below.

Chapter #2: *Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance*

The purpose of this systematic review was to examine the most up-to-date evidence on older driver training programs. This evidence was reviewed in accordance with three main outcomes, namely: 1) road safety knowledge; 2) self-perceived behind-the-wheel skills and behaviours; and 3) objectively measured driving performance.

Chapter #3: Older adults' motivations for participating in a 'tune-up' of their driving skills: A multi-stakeholder analysis

In this qualitative study, the perceptions of a range of stakeholders (i.e., older drivers, driving instructors, occupational therapists) were explored regarding older driver training, including the goals of such programs, as well as their design and delivery. The research question was: *What factors can influence older adults' participation in driver training?*

Chapter #4: Refreshing Older Adults' Driving Skills (ROADSkills): A randomized controlled trial examining the effect of video feedback

In the final study of this thesis, an older driver training program was created based on the best evidence (Chapter #2) and with input from stakeholders (Chapter #3). The effectiveness of this program (i.e., video feedback) was tested in a randomized controlled trial (RCT). The objectives of this RCT were as follows: 1) To determine the effectiveness of tailored video feedback on the on-road performance of older drivers compared to those who did not receive such feedback; 2) To determine the effectiveness of the feedback on self-reported driving behaviours and abilities, compared to those who did not receive such feedback.

Conclusion

Given the growing aging population, there is a corresponding need for programs aimed at addressing driving and community mobility in later life (MacDonald & Hébert, 2010). Healthcare professionals are often tasked with addressing medical fitness-to-drive, where there is also much potential to raise conversations about maintaining one's driving ability or planning for driver retirement (Dickerson et al., 2018). As an occupational therapist, I saw firsthand the devastating consequences when older adults were told they could no longer drive due to the onset or worsening of their medical conditions. Unfortunately, most had not prepared for the day when they could no longer drive. Developing a training program that focuses on improving driving abilities in later life can open up a conversation about driving and community mobility, which, in turn, can raise awareness about the impact of age- and health-related changes on behind-the-wheel abilities. By talking about driving before one's capacity is questioned for medical reasons or otherwise, we can strategize with older adults on how they might best access their out-of-home activities using transportation alternatives. By assisting in this way, we can help them remain active in their community for as long as possible. Using the very best evidence alongside stakeholder input, this thesis introduces the ROADSkills program, an approach that offers a potential context in which to raise the issue of driving and community mobility with older adults.

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Chapter Two: Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance

Preface

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Title Page

Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance

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Highlights

- Driver training programs for seniors can occur in classrooms and/or vehicles.
- The design, delivery, and impact of such programs were systematically reviewed.
- Tailored education, exercise and/or cognitive training can reduce their crash risk.
- Multidisciplinary approaches can improve seniors' driving and self-regulation strategies.
- Older driver training should be based on best evidence and evaluated accordingly.

Abstract

Introduction: Age- and health-related changes, alongside declines in driving confidence and on-road exposure, have been implicated in crashes involving older drivers. Interventions aimed at improving behind-the-wheel behaviour are diverse and their associated impact remains unclear. This systematic review examined evidence on older driver training with respect to 1) road safety knowledge; 2) self-perceived changes in driving abilities; and 3) behind-the-wheel performance.

Method: Nine databases were searched for English-language articles describing randomized controlled trials (RCTs) and non-RCTs of driver training interventions aimed at those aged 55+ who did not have medical or other impairments that precluded licensure. Quality appraisals were conducted using Cochrane's Risk of Bias Tool (RoB) and Risk Of Bias In Non-randomized Studies – of Interventions tool (ROBINS – I). [PROSPERO; registration no. CRD42018087366]

Results: Twenty-five RCTs and eight non-RCTs met the inclusion criteria. Interventions varied in their design and delivery where classroom-based education, or a combination of classroom-based education with on-road feedback, improved road safety knowledge. Training tailored to individual participants were found to improve self-perceived and behind-the-wheel outcomes, including crashes.

Conclusions: Interventions comprised of tailored training can improve knowledge of road safety, changes to self-perception of driving abilities, and improved behind-the-wheel performance of older drivers. Future research should compare modes of training delivery for this driver population to determine the optimal combinations of off- and/or on-road training.

Practical applications: Training programs aimed at older drivers should be supported by theory and research evidence. By conducting comparative trials with a sufficient sample size alongside well-defined outcomes that are designed in accordance with reporting guidelines, the most effective approaches for training older drivers will be identified.

Keywords:

Driver education; Crash rates; Refresher program; Driver training; Older adults

Introduction

Drivers aged 70 and older have the highest rate of motor vehicle collision (MVC)-related injuries and deaths (Tefft, 2017), attributable, in part, to their increasing frailty (Eberhard, 2008). Despite a downward trend in the number of MVC-related fatalities for this age group (NTSA, 2018; Tefft, 2017), health-related changes due to aging and the onset of medical conditions have been linked to their overrepresentation in crashes (Marshall et al., 2013). Lower rates of on-road exposure (Langford et al., 2013; Langford, Methorst, & Hakamies-Blomqvist, 2006), declines in driving confidence (Coxon et al., 2015), and behind-the-wheel errors (Cicchino & McCartt, 2015), have also been shown to negatively impact their driving. Research to-date has focused on improving older adults' driving safety given the link between this transportation mode and community engagement. Loss of licensure in older adulthood has been identified as a trigger for social isolation (The National Seniors Council, 2014), depression (Chihuri et al., 2016), and even having to relocate one's primary residence (Chihuri et al., 2016). While viable transportation alternatives may exist, older adults' access to these resources remain a challenge, especially for those living in rural communities (Levasseur et al., 2015). Without viable transportation alternatives to access their community, many older adults want and need to continue driving.

In their focus group study (n=79) that examined driving-related concerns among those aged 55-94, some of whom no longer had a license, Laliberte Rudman, Friedland, Chipman and Sciortino (2006) identified the value of behind-the-wheel training and/or remediation approaches for this age group. Study participants viewed such training as a potential means to reframe how the issue of driving and community mobility is raised by healthcare providers who primarily focus on medical fitness-to-drive. Laliberte Rudman et al. (2006) also suggested creating programs aimed at the 'well-elderly' (i.e., those for whom age- or health-related conditions do not impair daily functioning) to maintain their behind-the-wheel performance. Evidence specific to the effectiveness of such programs has increased over the last decade (Dickerson et al., 2017).

In the first systematic review to examine the state-of-evidence concerning older driver training interventions, Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, and Marshall (2007) concluded that classroom-based instruction alone was not effective in reducing MVCs, but could improve self-awareness of behind-the-wheel skills. At the time of their review, evidence concerning the impact of physical and cognitive training on driving was limited. An update of this review re-iterated the lack of effectiveness of classroom-based instruction on behind-the-wheel performance (Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009). Although findings by Korner-Bitensky et al. (2009) and subsequent systematic reviews (e.g., Golisz, 2014; Unsworth & Baker, 2014), have been helpful with classifying the types of interventions and detailing their associated findings, there is a dearth of evidence with respect to their specific impact on older drivers, including their effectiveness in changing behind-the-wheel behaviour, self-perceptions of driving ability, and road safety knowledge.

Systematic reviews conducted to date have yet to compare the design and delivery of training programs aimed at older drivers, as well as consider the theoretical rationale that inform such programs. Training approaches for novice drivers have been criticized for their lack of theoretical grounding (Dale, Scott, & Ozakinci, 2017; Poulter & McKenna, 2010) and evidence substantiating their instructional content and pedagogy (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002; Mayhew, 2007). Training programs aimed at both novice (Beanland, Goode, Salmon, & Lenné, 2013; Raftery & Wundersitz, 2011; Roberts & Kwan, 2001) and experienced drivers (Korner-Bitensky et al., 2009; Kua et al., 2007) need to be evaluated for their impact on road safety outcomes. Ensuring older drivers are up-to-date on their road safety knowledge, especially those who did not receive formal training upon initial licensure, has the potential to reduce bad habits accumulated over one's driving career (Keskinen, 2014). When combined with age-related changes in cognitive, physical and psychomotor functioning, poor driving habits can negatively impact a driver's ability to respond appropriately in emergency situations. Hence, such training programs should not only focus on age-related changes, but, as Keskinen (2014) noted, also provide seniors with "a better understanding of themselves, their health restrictions, their skills, and their abilities to ensure daily mobility" (p.14). Hatakka et al. (2002) raised the importance of understanding the effect of training on a driver's self-perception of their skills. In a recent systematic review that compared self-report and actual behind-the-wheel measures of driving behaviour, Kaye, Lewis, and Freeman (2018) emphasized how incorporating self-evaluation alongside objective assessments of one's driving can provide a more comprehensive account of the impact of training on older driver safety and community mobility.

Previous reviews of older driver training have examined interventions to understand if they change driving performance or reduce MVCs, but have not examined how such interventions impact road safety knowledge, self-perceptions of behind-the-wheel abilities, and objective measures of driving behaviour (e.g., on-road performance, collision risk). This knowledge gap limits evidence-based design and delivery of training targeting older drivers. The purpose of this systematic review was to examine evidence specific to these training programs. Studies were considered according to three primary outcomes: 1) knowledge related to road safety; 2) self-perceived behind-the-wheel skills and behaviours; and, 3) objective measures of driving performance.

Methods

The protocol for this review was registered with the international prospective register of systematic reviews (PROSPERO; registration no. CRD42018087366; https://www.crd.york.ac.uk/prospero/). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to structure this review (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

Eligibility Criteria

Studies were included if participants were community-dwelling adults aged 55 years or older and had a valid driver's license. Studies that focused on interventions specific to those with a medical diagnosis (e.g., Alzheimer's disease, stroke, Parkinson's Disease) or any other health-related impairments requiring driver rehabilitation were excluded. Eligibility of such studies was only considered if they reported results from a control and/or comparator group that met the inclusion criteria. Studies focused on the impact of vehicle modifications, advanced driver assistance systems, and/or roadway modifications only were excluded.

Studies were included if they addressed at least one of the following outcomes: 1) knowledge (e.g., related to road rules, defensive driving strategies, or awareness of the impact of aging, medication or medical conditions on driver performance); 2) self-perceived behind-the-wheel skills and behaviours (e.g., use of self-regulatory driving strategies, measures of behind-the-wheel confidence, and attitudes about driving cessation); and/or 3) objective measures of driving (e.g., MVCs, standardized on-road or simulator-based assessment of performance). A secondary outcome was the effect of the intervention on driver's license status (i.e., active driver vs. revocation of license vs. retired from driving).

Eligible study designs included randomized controlled trials (RCTs) and non-randomized comparative studies. Studies that compared interventions to no treatment or another treatment or usual care were included. Systematic reviews were excluded, but previous reviews were examined and relevant studies from these were included. Cross-sectional and cohort studies, qualitative research studies, conference presentations and proceedings, non-peer reviewed research literature, and thesis dissertations were also excluded.

Literature Search

Electronic databases were searched for English-language articles published prior to January 2018. Databases searched included: Cumulated Index to Nursing and Allied Health Literature (CINAHL) (1981 – 2018); MEDLINE (1946 – 2018); PsycINFO (1806 – 2018); Excerpta Medica Database (EMBASE) (1980 – 2018); Education Resources Information Centre (ERIC) (1966 – 2018); Allied and Complementary Medicine (AMED)

(1985 – 2018) ; AgeLine (1978 – 2018); the Cochrane Database (1999 – 2018); and Occupational Therapy systematic evaluation of evidence (OTseeker) (2003 – 2018). To identify additional relevant studies, the authors' own files were screened.

Preliminary database searches identified relevant key words for each concept (i.e., older adults, vehicle operation, and driver refresher programs) and their respective variations. A search strategy was initially developed for MEDLINE (**Table 1**), and then adapted for the remaining databases. The search strategy was developed in collaboration with a medical research librarian.

Study Selection

Results from each search were imported to an online screening management tool (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Duplicate citations were removed prior to title and abstract screening using this tool. Two reviewers independently screened the remaining citations and abstracts and resolved discrepancies through discussion. Full-texts of citations considered to be potentially relevant were retrieved and independently reviewed against the eligibility criteria by both investigators. Cohen's kappa coefficient (κ) was calculated to measure inter-rater agreement between the two reviewers at this stage, and interpreted using the framework described by McHugh (2012). Any discrepancies that arose between reviewers resolved through discussion or by consulting a third reviewer.

Data Extraction

Data were extracted by one reviewer and checked for accuracy by a second reviewer. A standardized chart was piloted for data extraction. Discrepancies arising in interpreting study information from the studies were resolved through discussion and consensus. Consultation with a third reviewer was not required.

Quality Appraisal

Using the Cochrane Risk of Bias (RoB) tool (Higgins & Green, 2011), RCTs were assessed independently by two reviewers. Each relevant item was rated as having low or high risk of bias, or unclear. Comparative non-RCTs were assessed for quality based on criteria outlined by the Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) tool (Sterne et al., 2016). Any discrepancies in bias assessment between the reviewers were resolved through discussion. As such, consultation with a third reviewer was not required. Problems with the design and execution of RCTs raise questions about the validity of their findings. Use of the RoB and ROBINS-I tools allowed authors to assess the degree of risk at which individual studies may be prone to bias (i.e., study findings may overestimate or underestimate the true intervention effect).

Data Synthesis

Included studies varied in their use of evaluative measures, hence, meta-analyses could not be conducted, and a narrative summary of the findings is presented. Findings capture study characteristics, intervention design, and effectiveness of outcomes by outcome type (i.e., knowledge related to road safety, self-perceived behind-the-wheel skills and behaviours, and objective measures of driving performance).

Results

Searches of electronic databases yielded 6742 citations after duplicates were removed. Following screening, a total of 132 studies were identified for which full-texts were retrieved. Of these studies, 32 met the inclusion criteria; an additional study published after the literature searches were completed was also identified (see **Figure 1**). There was strong agreement between raters at full-text review (κ = 0.90; proportion of conflicts = 0.04); conflicts were resolved through discussion. The body of evidence is comprised of 25 RCTs and 8 comparative non-RCTs (see **Table 2**).

Study Characteristics

Table 2 summarizes the general characteristics of the included studies. Most studies were conducted in the United States (n = 17), followed by Canada (n = 9), Australia (n = 2), Switzerland (n = 1), France (n = 1), and Japan (n = 1). Researchers from Belgium and The Netherlands collaborated on a single study (Cuenen et al., 2016).

The mean age of participants across studies varied from 68.3 years (Jacobs et al., 1997) to 80.3 years (Marottoli, Van Ness, et al., 2007); three non-RCT's grouped participants by age category (e.g., 65-74, 75-84) (Ichikawa, Nakahara, & Inada, 2015; Nasvadi & Vavrik, 2007; Vanlaar, Hing, Robertson, & Mayhew, 2016). Participant age varied from 55 years and older (Bédard, Isherwood, Moore, Gibbons, & Lindstrom, 2004; Bédard et al., 2008; Jacobs et al., 1997; Roenker, Cissell, Ball, Wadley, & Edwards, 2003), to 75 years and older (Coxon et al., 2017; Vanlaar et al., 2016).

Participants were recruited via radio and print advertisements (Bédard et al., 2004, 2008; Casutt, Theill, Martin, Keller, & Jäncke, 2014; Coxon et al., 2017; Marottoli, Van Ness, et al., 2007; Ostrow, Shaffron, & McPherson, 1992; Porter, 2013; Sawula et al., 2018; Tuokko, Rhodes, Love, Cloutier, & Jouk, 2015), mass mailing strategies (Edwards, Myers, et al., 2009; Tuokko et al., 2015), contacting seniors' programs in the community

(Anstey, Eramudugolla, Kiely, & Price, 2018; Ball, Edwards, Ross, & McGwin, 2010; Bédard et al., 2004, 2008; Caragata, Tuokko, & Damini, 2009; Coxon et al., 2017; Jacobs et al., 1997; Jones, Cho, Abendschoen-milani, & Gielen, 2011; Lavallière, Simoneau, Tremblay, Laurendeau, & Teasdale, 2012; Marottoli, Allore, et al., 2007; Marottoli, Van Ness, et al., 2007; Porter, 2013; Roenker et al., 2003; Ross, Freed, Edwards, Phillips, & Ball, 2017; Sawula et al., 2018; Tuokko et al., 2015), healthcare settings (Anstey et al., 2018; Ashman, Bishu, Foster, & McCoy, 1994; Ball et al., 2010; Bédard et al., 2004; Marottoli, Allore, et al., 2007; Marottoli, Van Ness, et al., 2007), and driving records provided by transportation authorities or other organizations (Ball et al., 2010; Coxon et al., 2017; Nasvadi & Vavrik, 2007; Ostrow et al., 1992; Owsley, McGwin Jr., Phillips, McNeal, & Stalvey, 2004; Owsley, Stalvey, & Phillips, 2003; Roenker et al., 2003; Ross et al., 2017; Vanlaar et al., 2016). All studies included male and female drivers but did not always indicate the respective gender distributions of participants. In studies where gender was reported, the proportion of females varied from 15.0% (Marottoli, Van Ness, et al., 2007) to 74.4% (Sawula et al., 2018). All studies targeted community-dwelling older adults where the number of participants ranged from 20 (Jacobs et al., 1997) to 2390 (Ross et al., 2017).

Characteristics of the Interventions

Interventions were grouped into three main categories: 1) *education-based*, 2) *physical exercise*, and 3) *cognitive training*. Some studies also described multi-component interventions that involved two or more of these categories. Table 2 details the components of each intervention by treatment arm. Theoretical underpinnings or models that informed their respective interventions were outlined in 12 of the 33 studies (Anstey et al., 2018; Caragata et al., 2009; Casutt et al., 2014; Coxon et al., 2017; Jones et al., 2011, 2012; Nasvadi & Vavrik, 2007; Owsley et al., 2004, 2003; Romoser & Fisher, 2009; Tuokko et al., 2015). Theories and models included: the Health Belief Model (HBM) (Rosenstock, 1974), Social Cognitive Theory (SCT) (Bandura, 1977, 1986b; Kohler, Grimley & Reynolds, 1999), the Precaution Adoption Process Model (PAPM) (Weinstein, Sandman, & Blalock, 2008), the Selection, Optimization and Compensation (SOC) Model (Baltes & Baltes, 1990), Self-Regulation Theory (SRT) (Kanfer, 1999), the Transtheoretical Model of Behaviour Change (TTM) (Prochaska & DiClemente, 1982), and the Goals for Driver Education (GDE) Framework (Hatakka et al., 2002). Some studies referred to models of cognitive processing, but did not name them specifically (Casutt et al., 2014). Adult learning principles were highlighted in the design of a single study (see Romoser & Fisher, 2009).

Education-based training interventions.

Interventions aimed to impart road safety knowledge to older drivers varied from the provision of the same content to all participants (i.e., group-based delivery) to those that were tailored to each individual. The content of group-based education covered a variety of topics, including road rules (Anstey et al., 2018; Ashman et al., 1994; Bédard et al., 2008; Lavallière et al., 2012; Nasvadi & Vavrik, 2007; Porter, 2013; Roenker et al., 2003; Sawula et al., 2018; Vanlaar et al., 2016), common driving errors and strategies for avoiding such errors (Ashman et al., 1994; Bédard et al., 2004, 2008; Ichikawa et al., 2015; Jacobs et al., 1997; Marottoli, Van Ness, et al., 2007; Nasvadi & Vavrik, 2007;

Roenker et al., 2003; Sawula et al., 2018; Vanlaar et al., 2016), self-regulatory driving strategies (Jones et al., 2011, 2012; Nasvadi & Vavrik, 2007; Sawula et al., 2018; Tuokko et al., 2015; Vanlaar et al., 2016), and/or an overview of how age-related and/or health impairments can influence driving (Bédard et al., 2004, 2008; Ichikawa et al., 2015; Jacobs et al., 1997; Jones et al., 2011, 2012; Nasvadi & Vavrik, 2007; Sawula et al., 2018; Tuokko et al., 2015; Vanlaar et al., 2016).

Group-based training was primarily delivered through government or not-for-profit agencies, such as the AAA *Safe Driving for Mature Operators/ Driver Improvement Program* (Ashman et al., 1994; Marottoli, Van Ness, et al., 2007); the AARP *55 Alive/Mature Driving Program; Seniors on the MOVE program* administered alone (Jones et al., 2011) or combined with the AARP-CarFit program (Jones et al., 2012). Education-based training was administered in classrooms at community halls, recreation or seniors' centres, (e.g., Anstey et al., 2018; Ashman et al., 1994; Bédard et al., 2004, 2008; Jones et al., 2011, 2012; Marottoli, Van Ness, et al., 2007), research sites (e.g., Jacobs et al., 1997), driving schools (e.g., Ichikawa et al., 2015), and a local theatre (Tuokko et al., 2015). Program duration varied from one (Ashman et al., 1994; Jacobs et al., 1997; Tuokko et al., 2015) to four sessions (Jones et al., 2011), with individual sessions ranging from less than one hour (Tuokko et al., 2015) to seven hours in a single day (Ashman et al., 1994). Group-based educational training was delivered by a highway patrol officer (Ashman et al., 1994), driving instructor (Anstey et al., 2018; Roenker et al., 2003; Vanlaar et al., 2016), trained actors (Tuokko et al., 2015), or by teams of professionals, such as a driving instructor and pharmacist (Jones et al., 2011).

Tailored education was typically office-based and/or involved on-road training. For example, one-on-one education aimed at promoting self-regulatory strategies, such as not driving at night or on highways, was delivered by optometrists and health educators at eye clinics (Owsley et al., 2004, 2003; Stalvey & Owsley, 2003). Other studies involved occupational therapists who provided the one-on-one education in a participant's home (Coxon et al., 2017). Content also varied across such training from educating older drivers on their positioning in a vehicle (Jones et al., 2012) to tailored instruction on self-regulatory strategies (Coxon et al., 2017; Owsley et al., 2004, 2003; Stalvey & Owsley, 2003).

Tailored feedback on behind-the-wheel performance was provided while participants were behind the wheel (Anstey et al., 2018; Bédard et al., 2008; Marottoli, Van Ness, et al., 2007; Sawula et al., 2018) or after completing a formal evaluation (Anstey et al., 2018; Ichikawa et al., 2015; Lavallière et al., 2012; Porter, 2013; Romoser & Fisher, 2009; Sawula et al., 2018). They also received feedback after receiving simulator training (Casutt et al., 2014; Lavallière et al., 2012; Romoser & Fisher, 2009; Sawula et al., 2018). Feedback was typically delivered by driving instructors (Ichikawa et al., 2015; Porter, 2013; Sawula et al., 2018) or researchers (Lavallière et al., 2012), although details of what their feedback encapsulated was not always reported. In some studies, participants viewed video recording of their real or simulated drives while also receiving feedback on their behind-the-wheel performance (Anstey et al., 2018; Lavallière et al., 2012; Porter, 2013; Romoser & Fisher, 2009; Sawula et al., 2018). One study had an occupational therapist provide feedback on participants' driving, which then informed their in-vehicle training by a driving instructor (Anstey et al., 2018).

Physical exercise interventions

Physical exercise interventions focused on improving range of motion, strength, dexterity, and coordination (Caragata et al., 2009; Marottoli, Allore, et al., 2007; Ostrow et al., 1992) as well as trunk stability and shoulder flexibility (Ashman et al., 1994). Such interventions varied in their level of tailoring. For example, Ashman et al. (1994) provided older drivers with the same home-exercise program. Similarly, Caragata et al. (2009) conducted a group-based exercise program at seniors' and recreation centres. In a study by Maratolli, Allore et al. (2007) older drivers received weekly home visits by a physiotherapist who tailored exercises to participant needs. Ostrow et al. (1992) also had a trained clinician (i.e., discipline not specified) conduct weekly home visits to monitor participant performance on a daily exercise regime, although no details were reported on adherence.

Cognitive training interventions

Cognitive training for older drivers typically focused on speed-of-processing (Ball et al., 2010; Edwards, Delahunt, & Mahncke, 2009; Edwards, Myers, et al., 2009; Roenker et al., 2003; Ross et al., 2016, 2017) memory (Ball et al., 2010; Cuenen et al., 2016; Edwards, Delahunt, et al., 2009; Edwards, Myers, et al., 2009; Ross et al., 2016, 2017), reasoning (Ball et al., 2010; Edwards, Delahunt, et al., 2009; Edwards, Myers, et al., 2009; Ross et al., 2016, 2017) and visual perception (Ashman et al., 1994). Ashman et al. (1994) provided participants with a range of potential activities that could be self-administered in their homes. Cuenen et al. (2016) delivered a computer-based working memory training program. Another protocol, the *Advanced Cognitive Training for Independent and Vital Elderly* (ACTIVE), has been tested in multiple included studies using two training arms: working memory and reasoning (Ball et al., 2010; Edwards, Delahunt, et al., 2009; Edwards, Myers, et al., 2009; Ross et al., 2016, 2017). Jacobs et al. (1997) administered a 2-hour cognitive training program in a driving simulator using specific scenarios. Cognitive training interventions were also tailored whereby participants received feedback after completing a series of computerized tasks including: reaction time, errors, and level achieved within the computer program (Casutt et al., 2014; Roenker et al., 2003). Trials evaluating the *Staying Keen In Later Life* (SKILL) programs used visuals depicting driving scenarios (Casutt et al., 2014; Edwards, Delahunt, et al., 2009; Edwards, Myers, et al., 2009).

Risk of bias of included RCTs

A summary of the results from the Cochrane's Risk of Bias assessment are provided in Figures 2 and 3. Allocation concealment strategies included providing research staff with participant allocation in sealed opaque envelopes (Porter, 2013), or using an external randomization service (Anstey et al., 2018; Coxon et al., 2017; Marottoli, Allore, et al., 2007).

Two RCTs did not specify if participants were blinded on their intervention that was delivered using desktop computers (Edwards, Myers, et al., 2009) or simulators (Rogé, Ndiaye, & Vienne, 2014). Evaluators of objective outcomes (i.e., scores on driving tests) were blinded to participant allocation except for in two studies (Ashman et al., 1994; Lavallière et al., 2012).

Ten RCTs reported short-term (i.e., post-intervention) outcome data. Of the RCTs that captured long-term outcomes (i.e., follow-ups), 11 adequately addressed missing data, if any. With regards to selective reporting, it was unclear whether three studies had a study protocol (Casutt et al., 2014; Roenker et al., 2003; Stalvey & Owsley, 2003). Sixteen studies did not report the results of data collected as mentioned in their methods. In other cases, only partial results of outcome measures were reported, precluding the ability to perform a meta-analysis.

Other concerns with risk of bias included: validity and reliability of outcome measures used (Jacobs et al., 1997; Stalvey & Owsley, 2003); likelihood of confounding or contamination on intervention effectiveness (Ashman et al., 1994; Bédard et al., 2004; Jones et al., 2011, 2012; Lavallière et al., 2012; Roenker et al., 2003); potential impact of attention bias (Anstey et al., 2018; Marottoli, Allore, et al., 2007; Ostrow et al., 1992; Owsley et al., 2004); and lack of adequate control group for at least one outcome (Bédard et al., 2008).

Risk of Bias of included non-RCTs

Eight of the 33 studies were assessed using the ROBINS-I tool (Caragata et al., 2009; Cuenen et al., 2016; Ichikawa et al., 2015; Nasvadi & Vavrik, 2007; Romoser, 2013; Romoser & Fisher, 2009; Tuokko et al., 2015; Vanlaar et al., 2016). Age and gender domains were considered confounding factors and assessed to be at a moderate risk of bias (Caragata et al., 2009; Cuenen et al., 2016; Ichikawa et al., 2015; Romoser, 2013; Tuokko et al., 2015; Vanlaar et al., 2016) and low risk (Nasvadi & Vavrik, 2007; Romoser & Fisher, 2009) in included studies. Risk of bias was also attributed to a lack of participant and/ or assessor blinding or authors not considering other confounding factors (e.g., participation in previous driver training programs). Bias due to deviations from the intervention was low for most studies except for one (Caragata et al., 2009), as only five of 19 participants allocated to their treatment group completed the intervention. Two studies were conducted at a population level, although they did not elaborate if any participants failed to receive the intended intervention or whether the study deviated from the protocol (Ichikawa et al., 2015; Vanlaar et al., 2016).

All studies were rated as low risk of bias for measurement of outcomes and selected reporting of results, except for Caragata et al. (2009) and Tuokko et al. (2015). Neither study blinded participants and their results were only reported for subscales of their self-report outcome measures. Caragata et al. (2009) had a large number of participants in their treatment group who were not assessed post-intervention. Tuokko et al. (2015) reported co-intervention as a potential confounder for their treatment and control group.

Examining interventions by outcome

Table 3 lists the outcomes examined in the current review alongside examples of measures used for evaluation. **Table 4** consolidates between-group differences alongside effect sizes across the outcomes of interest, which are synthesized accordingly (i.e., road safety knowledge, self-perceived and objective outcomes). Given the breadth of evaluation approaches used to assess intervention effectiveness, **Supplement A** provides a detailed narrative summary of findings from the included studies by their associated outcomes.

Knowledge of road safety

Older drivers' knowledge of road safety improved if participants attended all classroom-based group education sessions when compared to those who self-selected certain sessions (Jones et al., 2012). Knowledge also improved when attendance at a classroom-based session was combined with in-vehicle feedback (Marottoli, Van Ness, et al., 2007).

Self-perceived behind-the-wheel skills and behaviours

One-on-one education tailored to individual participants by a health care practitioner resulted in adoption of self-regulatory driving practices and self-reported avoidance of driving in complex situations (Owsley et al., 2004), while reducing self-reported driving exposure (Owsley et al., 2004, 2003; Stalvey & Owsley, 2003). Stalvey and Owsley (2003) described how a model of health behaviour change informed the intervention content and processes aimed at achieving changes to self-perceived behaviours. However, using the same model, Coxon et al. (2017) did not find a decrease in objective measures of driving exposure and driving space (i.e., distance driven beyond the home). None of the participants of these studies were blinded to their treatment allocation, potentially influencing their responses on the corresponding self-report measure of their driving habits.

Maintenance of self-reported driving space was observed for those who received computer-based speed-of-processing training when tailored to individual participants

(Edwards, Myers, et al., 2009). This finding was maintained in a three-year follow up (Edwards, Myers, et al., 2009; Ross et al., 2016). Intervention group participants' perceived difficulty with driving in complex situations did not change over this period compared to controls who reported more driving difficulties (Edwards, Myers, et al., 2009). Similarly, those receiving tailored speed-of-processing cognitive training were less likely than controls to cease driving at 3 year (Edwards, Delahunt, et al., 2009) and 10 year (Ross et al., 2017) follow-ups.

Objective measures of driving performance

Feedback from driving instructors that was tailored to individual participants' behind-the-wheel skills resulted in better on-road performance (Ashman et al., 1994; Bédard et al., 2008; Marottoli, Van Ness, et al., 2007; Sawula et al., 2018). On-road performance also improved when participants received tailored feedback on their driving in a simulator (Casutt et al., 2014), or when physical training activities were tailored to their specific abilities (Marottoli, Allore, et al., 2007; Ostrow et al., 1992). Rogé et al. (2014) demonstrated improvements in simulated driving performance for those receiving computerized field of view training that adapted the challenge level to their abilities and provided feedback on their performance in the training tasks.

Ball et al. (2010) found a decrease in the relative risk of MVC-involvement per year of driving exposure and mile driven following speed-of-processing cognitive training. Owsley et al. (2004) did not find any change in the relative rate of collision-involvement per mile driven or per years of active driving two years after one-on-one education to implement self-regulation strategies. Vanlaar et al. (2016) found a reduction in MVCs following population-level group-based education, whereas following tailored feedback, Ichikawa et al. (2015) did not.

Discussion

Summary of evidence

This systematic review aimed to examine evidence specific to the impact of driver training targeting community-dwelling healthy older adults with respect to their level of road safety knowledge, self-perceived behind-the-wheel skills and behaviours, and objective measures of on-road performance (e.g., driving errors, crashes). Of the 33 included studies, only two interventions demonstrated between-group differences and improvements in older adults' knowledge of road safety (Jones et al., 2012; Marottoli, Van Ness, et al., 2007). Key features of these interventions were participant attendance at educational sessions (Jones et al., 2012) and when in-class education with in-vehicle training were paired (Marottoli, Van Ness, et al., 2007). However, causative relationships between road safety knowledge and performance-based outcomes have yet to be established (Golisz, 2014; Korner-Bitensky et al., 2009; Kua et al., 2007). While our findings are similar to those of previous reviews where in-vehicle training for older drivers was found to reduce MVC, results from the current review go one step further by highlighting how tailoring the intervention can improve road safety knowledge and change self-perceptions of driving ability. The notion of a tailored intervention that emerged in this review is aligned with definition put forward by Kreuter et al. (2000; 1998):

> Any combination of information or change strategies *intended to reach one specific person*, based on characteristics that are unique to that person, related to the outcome of interest, and have been *derived from an individual assessment* (p.1).

A number of the included studies involved older drivers watching videos of themselves behind-the-wheel, while receiving feedback on their performance (Anstey et al., 2018; Porter, 2013; Sawula et al., 2018). Our findings highlight how intervention tailoring (e.g., driver feedback) varied across studies. As older driver training has shown promise in changing self-perceptions of driving and improving on-road performance as well as reducing MVCs in the short-term, future research should focus on examining the effectiveness of such interventions in the long-term.

Laliberte Rudman et al. (2006) recommended proactive approaches should be aimed at drawing older adults' attention to changes in their physical and cognitive abilities that could impact driving safety. Our findings suggest that training that involved discussions between older drivers and healthcare professionals increased self-regulatory driving practices (Owsley et al., 2004, 2003; Stalvey & Owsley, 2003). Likewise, tailored feedback from a driving instructor during video-based or in-vehicle training also improved driving performance (Ashman et al., 1994; Bédard et al., 2008; Marottoli, Van Ness, et al., 2007; Sawula et al., 2018). For any type of education to facilitate older adults' behaviour change, Tam (2014) emphasized the importance of leveraging individual experience and tailoring interventions concurrently.

A variety of professionals were responsible for delivering the interventions to older drivers attesting to how multi-disciplinary approaches can encourage behaviour change. For example, Anstey et al. (2018) described an approach whereby an occupational therapy assessment informed the behind-the-wheel feedback provided by a driving instructor. Such approaches have the potential to have a positive impact on older drivers (Hatakka et al., 2002; Keskinen, 2014) by ‘brushing up’ on their behind-the-wheel skills (Dickerson, Schold Davis, & Carr, 2018). Dickerson et al. (2018) have also highlighted the opportunity for innovative partnerships between driving instructors and primary care providers, such as occupational therapists, to support older adults to not only maintain their driving skills but also initiate the adoption of new transportation options.

Some studies included in this review aimed to induce self-regulatory driving practices and reduce driving exposure (Coxon et al., 2017; Owsley et al., 2004, 2003; Stalvey & Owsley, 2003). However, given the known association between heightened crash rates and low mileage, caution is warranted with regard to encouraging older adults to reduce their driving exposure (Antin et al., 2017). Changes in self-perception of driving ability may also not be congruous with actual behind-the-wheel skills. Kaye, Lewis and Freeman (2018) suggested that a combination of measures can better capture older drivers’ perceptions of their behaviour (e.g., perceived driving ability, confidence, self-regulation, situational avoidance) alongside objective measures of performance (e.g., on-road evaluation). Future research should focus on correlating self-perceived driving ability with actual driving ability at an individual (e.g., on-road performance) and population level (e.g., MVC-related outcomes).

There was limited evidence to suggest that tailored education delivered by a healthcare professional (Owsley et al., 2004) or speed-of-processing training (Ball et al., 2010) decrease relative rates of collision-involvement. However, observing the effects of such approaches using larger samples over longer periods might produce different results. While some studies did find a significant impact of population-level training on MVCs (Vanlaar et al., 2016), others have not found the same outcome (Ichikawa et al., 2015). To date, the limited body of evidence available examining this outcome remains inconclusive. Results from this systematic review suggest that a randomized-controlled trial, sufficiently powered for sample size, would be an important next step to evaluate the effectiveness of various training approaches on improving driving performance and reducing MVCs.

A major and ongoing challenge is the lack of a clear lexicon for older driver training and corresponding outcomes. For example, 'self-perception of driving' was defined and assessed in various ways across studies. Edwards et al. (2009) and Ross et al. (2016) both adapted a standardized tool (i.e., MDHQ) to assess *driving exposure*, which included items that may be more representative of self-perceptions of *driving difficulty*. Using taxonomies to name and frame outcomes, such as those suggested by the *Taxonomy and Terms for Stakeholders in Senior Mobility* (Transportation Research Board, 2016), may serve to facilitate future meta-analyses, which are needed to determine the effectiveness of older driver training approaches.

Sensitivity to detect change over time (i.e., responsiveness) is integral for any evaluative measure (see Law, 1987), yet none of the included studies addressed this aspect in their selection of assessments. Few studies reported the psychometric properties of their on-road assessment [e.g., intra-rater reliability (Porter, 2013); inter-rater reliability (Anstey et al., 2018; Marottoli, Van Ness, et al., 2007); construct validity

(Anstey et al., 2018)]. While examinations of clinically meaningful differences were provided in some studies (Anstey et al., 2018; Marottoli, Van Ness, et al., 2007; Sawula et al., 2018), test-retest reliability was not always reported. Future studies should report psychometric properties of their assessments, where possible.

Findings from this review suggest older drivers assigned to a 'control' group also demonstrated improvements in their driving (see Bédard et al., 2004; Casutt et al., 2014; Marottoli, Van Ness, et al., 2007; Porter, 2013). Participating in a study that focuses on driving can influence older adults' awareness of their behaviour even when not exposed to a training intervention (Bédard et al., 2004). Interestingly, no studies in the current review blinded participants to treatment allocation. While behind-the-wheel training was found to have a positive impact on driving in two studies (Anstey et al., 2018; Porter, 2013), the results were not statistically significant, which may be due, in part, to a lack of power (i.e., sufficient sample size) or treatment intensity (e.g., number of driver lessons). At minimum, future studies should indicate their efforts to reduce bias thereby allowing for higher confidence in their findings.

Methodological quality and heterogeneity of studies

All included studies had both male and female participants, yet only a single non-RCT (Nasvadi & Vavrik, 2007) conducted gender-based analyses. Additional sample characteristics (i.e., rural-/ urban-dwelling; socioeconomic status; literacy; health status) were not examined. Evidence suggests older driver training may have ceiling effects for those who perform well at baseline (Anstey et al., 2018; Marottoli, Van Ness, et al., 2007). As such, using self-appraisals of driving ability or in-vehicle driving evaluations may identify those who might benefit most from such training. Additionally, consistent reporting of group means at short- and long-term follow-ups, change in means, and/or effect sizes is critical for enabling comparisons across studies. Future systematic reviews of this evidence will benefit from peer-reviewed studies that adhere to reporting guidelines [e.g., CONSORT guidelines (Schulz et al., 2010)], include relevant supplemental information (e.g., additional results or intervention descriptions), and reference raw data or technical reports available in public domains.

Studies where interventions were found to be effective can be impacted by potential biases resulting from their trial design. For example, most RCTs in the current review did not use random sequence generators or implement strategies for allocation concealment (i.e., enlisting an individual not involved in the study to conduct group allocation). Older drivers in the same arm of the study could have experienced interventions differently depending on who was responsible for the delivery. There was also a lack of detail with regard to how training approaches were tailored to individual participants. Unsworth and Baker (2014) emphasized that older driver training programs should elaborate when describing the ‘dose’ of their respective intervention. Future studies would benefit from using guidelines developed for this purpose [e.g., Template for intervention description and replication (TIDieR) (see Hoffmann, Glasziou, Barbour, & Macdonald, 2014)].

Strengths and limitations of the current review

Best-practices for systematic reviews of evidence adhered to PRISMA guidelines (Moher et al., 2009). A broad search strategy was employed, including consultation with a medical librarian. All screening, data extraction, and quality assessments were conducted in duplicate. Despite these methodological strengths, challenges encountered in the current review may have impacted our findings. We did not include peer-reviewed studies if they did not use comparative research designs. As such, the described interventions may not fully reflect all available older driver training programs, including those in the grey or non-peer reviewed literature.

The review protocol classified driving status and collision involvement as secondary outcomes. However, the authors determined that these outcomes were critical, and so included as primary outcomes. Study authors were not contacted to provide additional or missing information. While such information can further inform strengths and limitations of interventions, meta-analyses was not possible from the included studies due to the diverse range of measures used to capture key outcomes.

Conclusion

This systematic review examined evidence specific to driver training interventions aimed at those aged 55+ who did not have any medical or other health-related impairments that precluded valid licensure. Results suggest interventions tailored to individual participants can change self-perceptions of driving and improve on-road performance. Older adults vary in their driving experiences, behind-the-wheel skills, and insights into their own abilities. As such, teaching strategies need to be tailored accordingly to ensure training interventions raise awareness of individual strengths and areas for improvement (Dickerson et al., 2017). If appropriate, explicating the causal relationships in theories and models for which an intervention is aimed (e.g., behaviour change) can highlight why some interventions are more effective than others, and for whom. Using this research, older drivers who might benefit most from certain interventions, but not others, can be identified. Interventions could then be tailored to their respective needs with the aim of reducing MVC risk and extending their years of safe driving. By encouraging collaborations between researchers, policy makers, service delivery providers and older drivers alongside best evidence, training programs can be developed that are feasible and impactful. Such programs also provide a critical opportunity to initiate conversations with older adults with regard to planning ahead for their transition from driving to other forms of transportation that support their out-of-home mobility.

Practical Applications

Evidence from this review found that tailored approaches can positively influence knowledge of road safety, change self-perceptions of driving and improve behind-the-wheel performance of older drivers. Results highlight the challenges of implementing older driver training in community-based settings. For example, Caragata et al. (2009) had to relocate their study due to low recruitment and being unable to fill the minimum number of participants required to run a program in a seniors’ centre. Programs for older drivers administered by transportation authorities have had a positive impact on reducing collision rates (Ichikawa et al., 2015; Vanlaar et al., 2016). Future studies should consider the influence of road safety policies [e.g., Vision Zero strategies (Tingvall & Haworth, 1999)] alongside the cost-effectiveness of delivering interventions aimed at improving the health and mobility of community-dwelling older adults.

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Figures

Figure 1. Flow of studies through the selection process

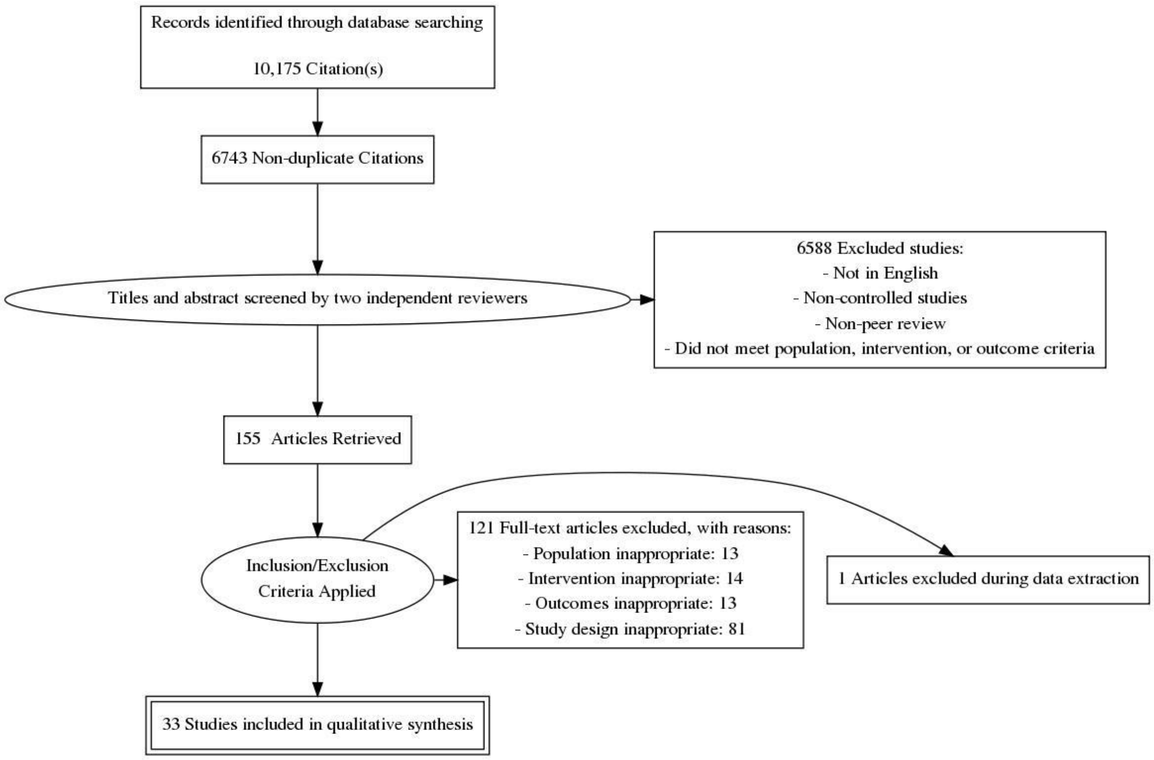

Figure 1 Diagram showing the flow of studies through the study selection process

Figure 2. Risk of bias summary

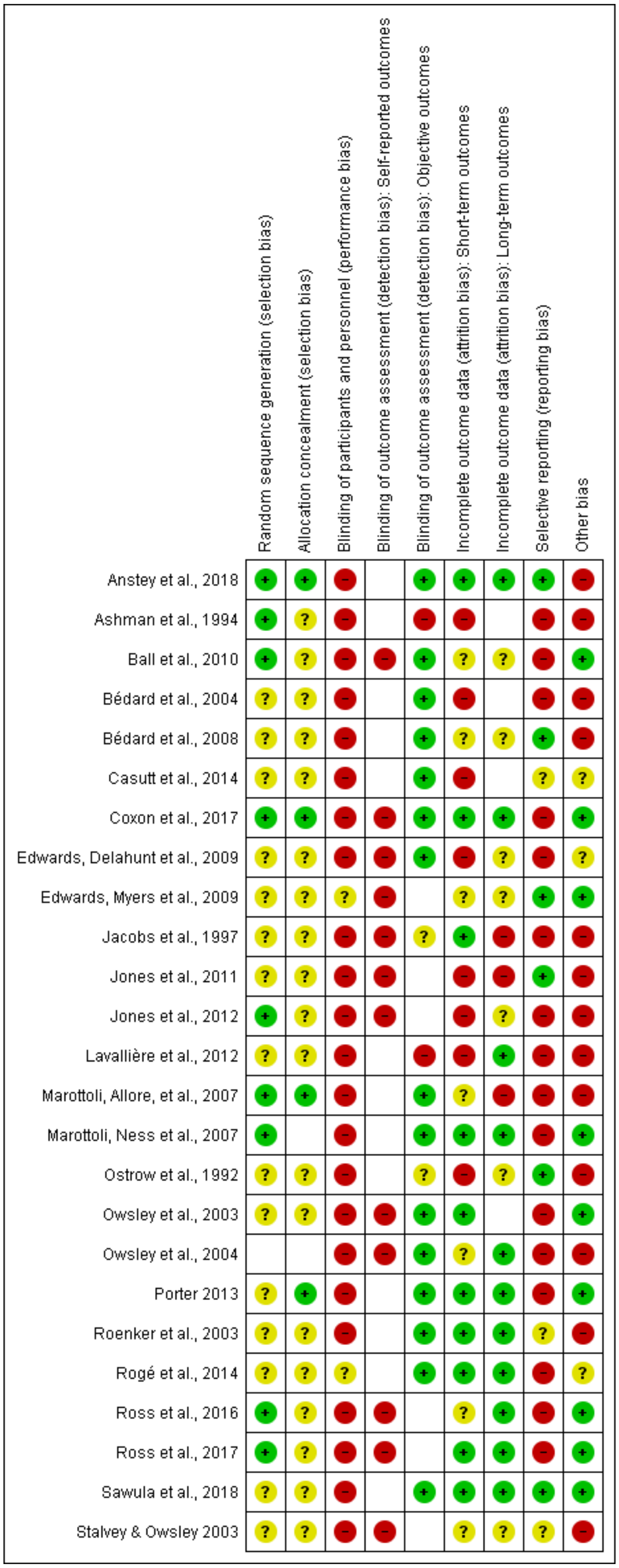

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study. Key: red = high risk of bias; yellow = unclear risk of bias; green = low risk of bias; blank = not applicable.

Figure 3. Risk of bias graph

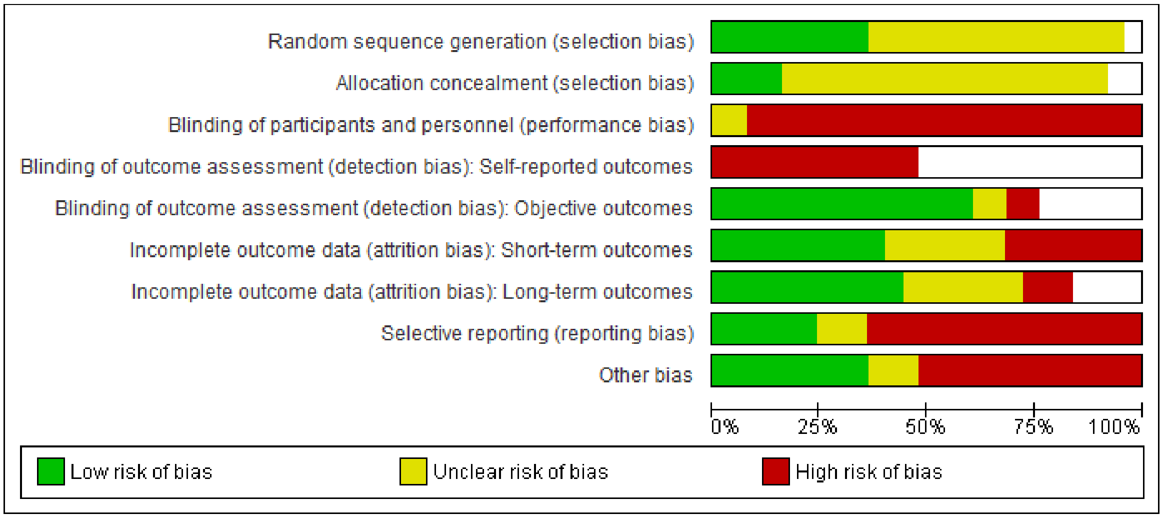

Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies (25 studies).

Tables

Table 1

Table 1 Search terms and search strategy for MEDLINE

MEDLINE
Years searched:1946-2018
Limits: English Language
Search Equation: (A AND ((B AND C) OR D))

Category A	**Category B**	**Category C**	**Category D**
Aged/ "Aged, 80 and over"/ Geriatrics/ Aging/ Aging.mp Ageing.mp Aging population.mp Ageing population.mp Older.mp Older Adult*.mp Elder*.mp Senior*.mp Mature.mp	Computer Simulation/ Simulat*.mp Simulation training.mp Education/ Educat*.mp Patient Education/ Health Education/ Rehabilitation/ Rehabilitat*.mp Intervention*.mp Occupational Therapy/ Occupational therap*.mp Feedback/ Feedback.mp Retrain*.mp Refresh*.mp Session*.mp In-vehicle.mp In-class.mp Course*.mp	Automobile Driving/ Automobiles/ Automobile* Automobile Driver Examination/ Drive/ Motor Vehicles/ Car.mp Cars.mp	((Driver OR drive OR driving OR car) adj3 (course* OR in-class OR in-vehicle OR session* OR refresh* OR retrain* OR feedback OR Occupational therap* OR Intervention* OR Rehabilitat* OR Educat* OR Simulat*))

Table 2

Table 2 Characteristics of included randomized controlled trials and non-randomized controlled trials.

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Randomized Controlled Trials					
Anstey et al. Australia (2018)	*N* = 55/57 *M*age (IG): 72.1 (5.7; 65, 85) *M*age (CG): 71.9 (5.4; 66, 86) 52.6% female	**(*n* = 27)** Group-based education: *Road Rules refresher course* 1x 2 hr sessions Community hall; Driving Instructor Driving feedback: In-vehicle training 2x 1hr sessions 7 days apart Own and Dual-brake vehicle; OT & Driving Instructor	Group-based education (*n* = 28) 1x 2 hr sessions Community hall; Certified Instructor	On-road driving performance Driving diary (mileage and self-reported collisions)	Significant between group difference in reduction of critical/ dangerous driving errors (p = .008). No significant difference in on-road driving performance (p = .117) No significant difference in mileage and collisions (p > .10).
Ashman et al. United States (1994)	*N* = 94/ 105 *M*age (Males): 72.6 (65,88) *M*age (Females): 70.9 (65, 84) 51 % female	**IG1 (*n* = 18)** Individualized education: Physical exercises 4x/week for 8 weeks Self-administered in-home **IG2 (*n* = 10)** Individualized education: Visual perceptual training 20mins 4x/week for 8 weeks Self-administered in-home **IG3 (*n* = 15)** Group-based education: *AAA Safe Driving for Mature Operators* 1 x 8-hour session Classroom; Highway Patrol Officer **IG4 (*n* = 15)** IG1 + IG3 **IG5 (*n* = 19)** IG2 + IG3	No intervention (*n* = 17) [Each intervention also compared to each other]	On-road driving performance	All interventions resulted in significantly better performance compared to control (p < .05). No one intervention was better than the other following pair-wise comparison (p > .001)
Ball et al. United States (2010)	*N* = 908/ 908 *M*age: 73.1 (65, 91) 73 % female	*ACTIVE* **IG1 (*n* = 145)** Group-based education: Memory training	No intervention (*n* = 407)	MVC involvement [MHDQ: Self-reported driving mileage extracted	Reasoning training significantly reduced MVC involvement per year of

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
		10x 70min sessions for 5 weeks Study site; Trainer **IG2 (*n* = 175)** <u>Group-based education:</u> Reasoning Training 10x 70min sessions for 5 weeks Study site; Trainer **IG3 (*n* = 179)** <u>Computer-based training:</u> Speed-of-Processing/ Visual attention training 10x 70min sessions for 5 weeks Study site; Trainer		to inform MVC per mile driven]	driving exposure [RR .52, 95% CI, .31-.87] and per person mile driven [RR .57, 95% CI, .34-.96]. Speed-of-processing training significantly reduced MVC involvement per year of driving exposure [RR .44, 95% CI, .24-.82] and per person mile driven [RR .50, 95% CI, .27-.92] Memory training had no significant association.
Bédard et al. Canada (2004)	N = 65/ 72 *M*age: 71.09 (±7.49; 55, 86) 52 % female	**(sample size by group not reported)** <u>Group-based education</u>: *55 Alive/ Mature Driving* 2x 1.5 hr sessions over 8 weeks Senior's Centre; Certified Instructor	No intervention	On-road driving performance	No significant group differences (p-value not reported).
Bédard et al. Canada (2008)	N = 75/ 75 *M*age: 75.0 (± 6.04; 65, 87) 54.7 % female	**(*n* = 38)** <u>Group-based education:</u> *55 Alive/ Mature Driving* 2x 1.5 hr sessions over 8 weeks Classroom; Certified Instructor <u>Driving feedback:</u> In-vehicle training 2x 1hr sessions over 8 weeks Own or Dual-brake vehicle; Driving Instructor	No intervention (n = 37)	On-road driving performance [Driving knowledge – pre-post for IG only]	Intervention group performed significantly better than control ($p < .05$).
Casutt et al. Switzerland (2014)	N = 77/ 91 *M*age: 72.36 (±5.61; 62-87) 29 % female	**IG1 (*n* = 31)** <u>Driving feedback:</u> Simulated driver training 10x 40mins sessions over 7 weeks Driving simulator **IG2: (*n* = 23)** <u>Computer-based training:</u> Attention training 10x 40mins over 7 weeks Computer	No intervention (n = 26)	On-road driving performance	Intervention group 1 performed significantly better than intervention group 2 ($p < .05$). Neither treatment differed from controls ($p > .05$).

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Coxon et al. Australia (2017)	*N* = 366/ 380 *M*age (IG): 80 (±4) *M*age (CG): 80 (±4) 39 % female	**(*n* = 183)** <u>Individualized education:</u> *Behind the Wheel* (adapted from *KEYS*) 2x 1-2 hr sessions over 1 month Home-based; Occupational Therapist	No intervention (*n* = 183)	Driving exposure (mileage) Alternative transportation Use of self-regulation strategies KAP: Community participation MHDQ: Driving space	Intervention group did not differ from control group on any measures [i.e., driving exposure (p = .57), alternative transportation (p = .90), KAP (p = .31), driving space (p = .88)], except willingness to adopt self-regulatory driving practices (p = .02).
Edwards, Delahunt, et al. United States (2009a)	*N* = 550/ 568 *M*age (IG): 74 (± 5.54) *M*age (CG): 75 (± 6.01) Both groups (min, max): (63, 91) 70 % female	**(*n* = 276)** <u>Computer-based training:</u> Speed-of-processing training 10x 1 hr sessions over 5 weeks Desktop computer; Trainer	Social contact (internet use) or No intervention (*n* = 274)	MHDQ: Driving status	Intervention group were 40% less likely to report stopping driving within a 3-year follow up compared to controls (p = .048).
Edwards, Myers, et al. United States (2009b)	*N* = 134/ 134 *M*age (IG): 74.13 (± 4.91) *M*age (CG): 74.52 (± 5.69) (Gender not reported)	**(*n* = 66)** <u>Computer-based training:</u> Speed-of-processing training 10x 1 hr sessions over 5 weeks Desktop computer; Trainer	Internet use for social/ computer contact (n = 68) [Low-risk reference group not included (n = 366)]	MHDQ: Driving exposure MHDQ: Driving space MHDQ: Driving difficulty	Intervention group did not differ from control group over 3 years in outcome-measure composite scores (p > .05).
Jacobs et al. United States (1997)	*N* = 20/ 21 *M*age: 68.3 (±7.4) (Gender not reported)	**IG1 (*n* = 6)** <u>Educational videos:</u> Videos of simulated drives 1x 1-hour session [2 videos] Classroom **IG2 (*n* = 7)** <u>Simulator-based training:</u> Simulated driving training + IG1 1x 2-hour session [4 videos] Driving simulator	No intervention (*n* = 8)	On-road driving performance Driving difficulties	Post-test driving performance was significantly different between groups (p = .05).
Jones et al. United States (2011)	*N* = 58/ 77 *M*age: 70.9 (±4.47; n/a) 53.4 % female	**(*n* = 33)** <u>Group-based education:</u> *Seniors On the Move* 4x 2 hr sessions for 4 weeks Classroom; Multi-disciplinary team	No intervention (*n* = 25)	Driving habits Driving experiences	Intervention group did not differ from control group (p > .05).

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Jones et al. United States (2012)	*N* = 44/ 47 *M*age: 79 (± 7.1; n/a) 57 % female	**(*n* = 20)** Group-based education [High Intensity]: *SOM-A* + CarFit (optional) 4x 2hr sessions for 4 weeks Classroom; Multi-disciplinary team	*SOM- B* (*n* = 24) Group-based education [Low Intensity] 1x 2hr session + 2 optional sessions for 4 weeks Classroom; Multi-disciplinary team	Driving knowledge Driving behaviour	High intensity group performed better on knowledge test ($p = .01$), and significantly increased in self-reported seatbelt use ($p = .01$), compared to low intensity.
Lavallière et al. Canada (2012)	*N* = 22/ 22 *M*age (IG): 72.1 (± 5.3) *M*age (CG): 69.3 (± 4.5) 32 % female	**(*n* = 10)** Group-based education: *55Alive/Mature driving* 3x 40 mins sessions over 2 weeks Classroom; Course Instructor Simulated Driving + Driving Feedback: Simulated driving training feedback 3x 15 mins sessions over 2 weeks Driving simulator; Researcher	Group-based education + Simulator training (*n* = 12)	On-road driving performance	Visual search strategies while driving improved more in the intervention group than control ($p < .01$).
Marottoli, Allore, et al. United States (2007a)	*N* = 174/ 178 *M*age (IG): 77.4 (± 3.9) *M*age (CG): 77.2 (±4.6) 32 % female	**(*n* = 84)** Individualized Education: Physical exercise + home-safety education 15 mins daily for 12 weeks; Weekly visit with physiotherapist Self-administered in-home	Individualized home-safety education (*n* = 90) Monthly In-home; Research Assistant	On-road driving performance	Intervention group performed better on road test than control ($p = .03$).
Marottoli, Van Ness, et al. United States (2007b)	*N* = 118/ 126 *M*age (IG): 80.8 (± 4.7) *M*age (CG): 79.7 (± 4.6) IG: 16 % female CG: 14 % female	**(*n* = 69)** Group-based education: *AAA Safe Driving for Mature Operators* 2x 4 hr hour session over 8 weeks Classroom; Certified Instructor Driving feedback: In-vehicle training 2x 1hr sessions over 8 weeks Driving Instructor	Modules on vehicle home and environment safety (*n* = 57)	On-road driving performance Driving knowledge	Intervention group improved significantly more on road test ($p = .001$) and knowledge ($p < .001$) compared to control.
Ostrow et al. United States (1992)	*N* = 32/ 38 *M*age (IG): 69.01 (± 4.97) *M*age (CG): 70.67 (± 6.87)	**(*n* = 16)** Individualized education: Physical exercise Weekly sessions for 8 weeks	No intervention (*n* = 16)	On-road driving performance	Intervention group significantly improved in driving skills of vehicle

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
	IG: 69 % female CG: 75 % female	Home-based; Clinician		Self-reported driving mileage	handling ($p < .05$) and observation ($p < .05$). No differences in mileage ($p > .05$).
Owsley et al. United States (2003)	*N* = 365/ 385 *M*age: 74 (± 6; 60, 91) 31 % female	**(*n* = 194)** <u>Comprehensive eye examination:</u> Optometrist check-up 1 time prior to education Clinic; Optometrist <u>Individualized education:</u> *KEYS* 2x 1-2 hr sessions over 1 month Home-based; Health Educator	Usual Care (*n* = 176)	MDHQ: Driving avoidance MDHQ: Driver dependency MDHQ: Driving exposure MDHQ: Driving difficulty DPPQ: Attitudes DPPQ: Self-regulatory practices	At 6 months post-intervention, intervention group significantly reported increased driving difficulty ($p < .01$) and driving avoidance ($p < .01$), reduced driving exposure ($p < .05$), increased self-regulatory practices ($p < .01$).
Owsley et al. United States (2004)	*N* = 338/ 403 *M*age (IG): 73.7 (± 6.0) *M*age (CG): 73.3 (± 6.2) IG: 34.2 % female CG: 27.3 % female	**(*n* = 162)** <u>Comprehensive eye examination:</u> Optometrist Check Up 1 time prior to education Clinic; Optometrist <u>Individualized education:</u> *KEYS* 2x 1-2 hr sessions over 1 month Home-based; Health Educator	Usual Care (*n* = 176)	MVC involvement MDHQ: Driving exposure MDHQ: Driving avoidance DPPQ: Self-regulatory practices	No between-group differences in crash rates per 100 person-years of driving (RR 1.08, 95% CI .71-1.64) or per 1 million person-miles of travel (RR 1.40, 95% CI, .92-2.12). At 2 years post-intervention, intervention group reported increased driving avoidance ($p < .0001$) and self-regulatory ($p < .0001$).
Porter Canada (2013)	*N* = 54/ 55 *M*age (IG1): 77.6 (± 7.1) *M*age (IG2): 77.1 (± 5.8) *M*age (CG): 73.6 (± 4.6) IG1: 41.2 % female IG2: 38.9 % female CG: 42.1 % female	**IG1 (*n* = 18)** <u>Group-based education:</u> *55 Alive/ Mature Driving* 2x 4hr sessions over 1 week **IG2 (*n* = 17)** <u>Individualized education:</u> Feedback on video of in-vehicle driving + IG1 1x 90 mins session Videos and GPS data; Driving Instructor	No intervention (*n* = 19)	On-road driving performance	No between-group differences ($p > .05$).

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Roenker et al. United States (2003)	*N* = 95/ 104 *M*age (IG1): 72.35 (± 5.36; 63, 81) *M*age (IG2): 72.08 (± 6.82; 59, 86) *M*age (CG): 69.00 (± 6.85; 55, 80) (Gender not reported)	**IG1 (*n* = 22)** Group-based education: Road rules and safety education 2x 2hr sessions over 1 day Driving instructor Simulator driving: Simulator Training Practice over one day Driving simulator Safety demonstration: In-vehicle demonstration 1hr over one day In-vehicle; Driving Instructor **IG2 (*n* = 48)** Computer-based training: Speed-of-processing training 4.5 hr average over one day Computer	No intervention (*n* = 25) [Low-risk reference group]	On-road driving performance	Overall on-road performance did not change over 18 months (p-values not reported). Significant differences, favouring IG2, were seen in 5 [dangerous maneuvers ($p < .24$), signals ($p < .001$), turning ($p < .002$), changing lanes ($p < .023$), position in traffic ($p < .032$) of 8 composite scores.
Rogé et al. France (2014)	*N* = 31/ 33 *M*age: 70 (63, 78) 25.8 % female	**(*n* = 15)** Simulator driving: Useful field view training + Feedback 2x 5 hr sessions over 1 day Table-top simulator	Simulator training following vehicle (*n* = 16)	Simulated driving performance	Intervention group detected pedestrians significantly sooner than the control ($p = .04$).
Ross et al. United States (2016)	*N* = 1806/ 1806 *M*age (IG): 73.13 (± 5.55) *M*age (CG1): 73.21 (± 5.87) *M*age (CG2): 73.60 (± 5.78) IG: 73.6 % female CG1: 74.3 % female CG2: 71.4 % female	**(*n* = 598)** Computer-based training: Speed-of-processing training 10x 60-75min sessions over 6 weeks Computer; Certified Trainer [Half received a booster session]	**CG1 (*n* = 610)** Single-component memory training Group-based education 10x 60-75 mins sessions over 6 weeks Certified Trainer [Half received a booster session] **CG2 (*n* = 598)** No intervention	MDHQ: Driving frequency MDHQ: Driving exposure MDHQ: Driving space	No significant differences between groups ($p > .05$). Those that received a booster session of the intervention maintained driving exposure ($p < .05$) and frequency ($p < .05$).
Ross et al. United States (2017)	*N* = 2390/ 2402 *M*age: 73 (± 5.70; 65, 91) 73.2 % female	*ACTIVE* **IG1 (*n* = 610)** Group-based education: Memory training 10x 70min sessions for 5 weeks	No intervention (*n* = 598)	MDHQ: Driving status	No significant differences between training and no-training groups ($p > .05$).

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
		Study site; Trainer **IG2 (*n* = 596)** <u>Group-based education:</u> Reasoning Training 10x 70min sessions for 5 weeks Study site; Trainer **IG3 (*n* = 598)** <u>Computer-based training:</u> Speed-of-Processing/ Visual attention training 10x 70min sessions for 5 weeks Study site; Trainer [Half received a booster session]			
Sawula et al. Canada (2017)	*N* = 78/ 78 *M*age: 72.45 (± 5.34; 65, 88) 74.4 % female	**IG1 (*n* = 25)** <u>Group-based education:</u> Basic Training <u>In-vehicle Training:</u> On-road practice + Feedback 2x 45 mins sessions over 1week Own vehicle; Driving Instructor **IG2 (*n* = 26)** <u>Group-based education:</u> Basic Training <u>In-vehicle Training:</u> On-road practice + Feedback <u>Simulator Training:</u> Simulator driving + feedback 1x 45 min session over 1 day Driving simulator; Research Assistant	**CG (*n* = 27)** Single-component – Basic Training <u>Group-based education</u> 1x 3 hr session over 1 day Classroom; Qualified Instructor	On-road driving performance Driving knowledge	Significantly decreased driving errors following both interventions compared to control ($p < .01$). Both intervention groups significantly improved in vehicle control ($p < .01$) and observation ($p < .001$)
Stalvey & Owsley United States (2003)	*N* = 365/ 385 *M*age: 74 (± 6; 60, 91) 31 % female	**(*n* = 194)** <u>Comprehensive eye examination:</u> Optometrist check-up 1 time prior to education Clinic; Optometrist <u>Individualized education:</u> *KEYS* 2x 1-2 hr sessions over 1 month Home-based; Health Educator	Usual Care (*n* = 171)	DPPQ	Intervention group had a higher awareness of impact on driving due to vision impairment ($p < .01$), benefits of self-regulation ($p < .01$), and willingness to consider and make changes ($p < .01$).

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Non-Randomized Controlled Trials					
Caragata et al. Canada (2009)	*N* = 24/ 26 *M*age (IG): 76.3 (62, 87) *M*age (CG): 74 (71, 76) 73.2 % female	**(*n* = 19)** Group-based education: Physical exercise 12x 1 hr sessions over 6 weeks Seniors Centre	No intervention (*n* = 5)	MDHQ: Driving exposure	No between-group investigations reported.
Cuenen et al. Belgium & The Netherlands (2016)	*N* = 56/ 84 *M*age (IG): 70.84 (±4.66) *M*age (CG1): 69.84 (±4.39) *M*age (CG2): 73.06 (±6.2) (Gender not reported)	**(*n* = 19)** Computer-based training: Adaptive working memory training Daily over 25 days Home-based; Self-administered	No intervention (*n* = 18) Non-adaptive working memory training (*n* = 19) Computer-based training Daily over 25 days Home-based; Self-administered	Simulated driving performance	No significant differences between groups ($p > .05$).
Ichikawa et al. Japan (2015)	(Sample size not reported) Age categories: 65-69, 70-74, 75-79, 80+ (1986 - 2011) 31 % female	License renewal for drivers age 70+: Group-based education: Road rules and safety 1x 30 mins over 1 day every 3-5 years Discussion session: Feedback on driving 1x 30 mins over 1 day every 3-5 years Driving school; trained instructor	License renewal for drivers age 65-69: Road rules and safety + vision test	MVC involvement	No reduction in at-fault collisions (RR and 95% CI not reported).
Nasvadi & Vavrik Canada (2007)	(Sample size not reported) Age categories: 55-74; 75-95 61.15 % female	**(*n*= 74)** Group-based education: *55 Alive/ Mature Driving* 2x 1.5 hr sessions over 8 weeks	No intervention (*n* = 65)	MVC involvement	No significant difference between groups ($p = .078$).
Romoser & Fisher United States (2009)	*N* = 54/88 *M*age: 77.54 (±4.55; 70, 88) (Gender not reported)	**IG1 (*n* =18)** Simulator Driver Training: Simulator-based training 1x 60 min session over 1 day Driving simulator Driving Feedback: Simulator Feedback 1x 60 min session over 1 day Driving simulator & field drives **IG2 (*n* = 18)** Group-based Education: Secondary look training 1x 60 mins session over 1 day	No intervention (*n* = 18)	Simulated driving performance On-road driving performance	IG1 improved significantly more than IG2 ($p < .05$) and controls ($p < .001$) on simulated driving performance. IG1 improved significantly more than IG2 ($p < .005$) and controls ($p < .005$) on on-road driving performance.

First Author; Country; (Year)	Participants: Sample Size (n = # completed intervention/ # enrolled) Mean Age (SD; min, max) Gender (% female)	Intervention(s) and Intervention Details Type Delivery Format Duration & Frequency Setting/ Materials/ Provider	Control Intervention(s)	Outcome(s) of interest	Key Findings
Romoser United States (2013)	*N* = 21/24 *M*age IG: 77.4 (±3.47; 73, 82) *M*age CG: 76.5 (±3.2; 72, 81) (Gender not reported)	**(*n* =11)** + Feedback Simulator Driver Training: Simulator-based training 1x 60 min session over 1 day Driving simulator Driving Feedback: Simulator and in-vehicle driving feedback 1x 60 min session over 1 day Driving simulator & field drives	No intervention (*n* = 10)	On-road driving performance	No between-group investigations reported.
Tuokko et al. Canada (2015)	*N* = 193/ 210 *M*age (IG): 77.4 (±3.47; 73,82) *M*age (CG): 76.5 (±3.2; 72-81) 70 % female	**(*n* = 110)** Group-based education: Play on Road Safety 1x 50 min session over 1 day Theatre; Actors	Print resources (*n* = 100)	Driving attitudes	No significant differences between groups ($p > .05$).
Vanlaar et al. Canada (2016)	(Sample size not reported) Age categories: 75-79; 80-83 (Gender not reported)	Group-based education: *GES* 1x 90 min session over 1 day every 2 years Classroom; Driving Improvement Counsellor	No intervention	MVC involvement	No significant differences between groups ($p > .05$).

AAA = American Automobile Association; ACTIVE = Advanced Cognitive Training for Independent and Vital Elderly ; B & BI = Behaviours and Behavioural Intentions; CG = Control Group; IG = Intervention Group; DPPQ = Driving Perception and Practice Questionnaire; GES = Group Education Session; KAP = Keele Assessment of Participation; KEYS = Knowledge Enhances Your Safety; MDHQ = Mobility Driving Habits Questionnaire; MVC = Motor Vehicle Collision; SKILLS = Staying Keen In Later Life; SOM = Seniors on the MOVE (Mature Operators Vehicular Education).

Table 3

Table 3 Outcome domains of interest with examples of measures from included studies

Outcome examined in this systematic review	**Examples of domains investigated by included studies and evaluation tools**
Knowledge of Road Safety	Road rules for traffic safety (e.g., pen and paper tests)
Self-perceived behind-the-wheel skills and behaviours	Driving Status (e.g., MDHQ: license status)
	Driving Exposure (e.g. MDHQ: how often and how frequently one drives)
	Perceived Driving Difficulty (e.g. MDHQ: level of difficulty perceived in complex everyday driving situations)
	Driving Space (e.g. MDHQ: how far beyond the home one drives)
	Attitudes towards Driving/ Use of Self-regulation Strategies (e.g. DPPQ; willingness to avoid driving in rush hour or in bad weather)
	Community Participation/ Use of Alternative Transportation
Objective measures of driving performance	Driving errors during naturalistic driving (e.g., On-road tests drawing from evaluations used by transportation authority or standardized tests developed for research)
	Driving errors during simulated driving (e.g., secondary looks while turning left at an intersection, visual field and visibility, driving speed and stopping at a stop sign)
	Crashes and collisions
	Driving Exposure (e.g., Data logging devices using GPS)

DPPQ = Driving Perception and Practice Questionnaire; GPS = Global positioning systems; MDHQ = Mobility Driving Habits Questionnaire

Table 4

Table 4. Raw data on between-group changes alongside reported effect sizes by outcome

Author, Year	Sample size (*n*) (Intervention + control)	Within group changes	Reported *p*-values	Type of Effect Reported	Effect Size Reported
Outcome: Knowledge of Road Safety					
Jones et al. (2012)	44	Ix [*mean change* (SD): 3.70 (2.0)] Control [*mean change* (SD): .87 (2.6)]	**< .01**	Raw group mean difference	2.83
Marottoli, Van Ness et al. (2007)	92	Ix [*least square mean change* (SE): 4.60] Control [*least square mean change* (SE): 1.16]	**< .001**	Raw group mean difference	3.45
Outcome: Self-perceived behind-the-wheel skills and behaviours					
[*Driving Status*]*					
Edwards, Delahunt et al. (2009)	550	Ix [*n* (%): 39 (14)] Control [*n* (%): 24 (9)]	**.048**	Hazard Ratio	.586 (95% CI = .356-.995)
Owsley et al. (2003) [Dependency on others to drive]	365	Not Reported	.14	T-statistic	*t*(1, 361) = 1.44
Ross et al. (2017)	257 (Ix I vs. Control)	Not Reported	**< .05**	Hazard Ratio	.45 (95% CI = .24 - .86)
	252 (Ix II vs. Control)		**< .05**		.51 (95% CI = .28 - .94)
	267 (Ix III vs. Control)		> .05		.81 (95% CI = .47-1.41)
	324 (Ix I + Booster vs. Control)		> .05		.61 (95% CI = .31-1.22)
	336 (Ix II + Booster vs. Control)		**< .05**		.30 (95% CI = .11-.82)
	336 (Ix III + Booster vs. Control)		> .05		.69 (95% CI = .34-1.4)
[*Driving Exposure*]					
Anstey et al. (2018)	55	Ix [1175.5 (566.3)] Control [979.7 (585.3)]	> .1	Not Reported	Not Reported
Edwards, Myers, et al. (2009)	500	Not Reported	**.039**	F-Statistic	*F*(2, 493) = 3.27
Jones et al. (2011) [High driving risk exposure]	70	Ix [*mean change* (SD): -.26 (.70)] Control [*mean change* (SD): -.19 (.51)]	.95	Not Reported	Not Reported
Jones et al. (2011) [Low driving risk exposure]	70	Ix [*mean change* (SD): -.14 (.60)] Control [*mean change* (SD): -.18 (.64)]	.73	Not Reported	Not Reported
Ostrow et al. (1992)	32	Not Reported	< .5	F-Statistic	*F*(7, 232) = 1.00
Owsley et al. (2003) [Self-reported trips per week]	365	Not Reported	**< .02**	T-Statistic	*t*(1, 361) = 2.26
Owsley et al. (2004)	338	Not Reported	**.02**	Not Reported	Not Reported

Author, Year	Sample size (*n*) (Intervention + control)	Within group changes	Reported *p*-values	Type of Effect Reported	Effect Size Reported
[Self-reported trips per week]					
Ross et al. (2016)	1196	Not Reported	**< .05**	Cohen's *d*	.6
[*Driving Difficulty*]					
Edwards, Myers, et al. (2009)	500	Not Reported	**< .001**	F-Statistic	*F*(2, 493) = 11.99
Owsley et al. (2003) [Frequency of avoidance]	365	Not Reported	**< .01**	T-Statistic	*t*(1, 360) = 6.21
Owsley et al. (2004) [Frequency of avoidance]	338	Not Reported	**< .0001**	Not Reported	Not Reported
[*Driving Space*]					
Coxon et al. (2017)	366	Not Reported	.88	Odds Ratio	1.04 (95% CI = .65-1.66)
Edwards, Myers, et al. (2009)	500	Not Reported	**.036**	F-Statistic	*F*(2, 493) = 3.35
Ross et al. (2016)	1196	Not Reported	> .05	Not Reported	Not Reported
[*Attitudes towards driving and use of self-regulatory strategies*]					
Coxon et al. (2017)	366	Not Reported	**.02**	Odds Ratio	1.6 (95% CI = 1.1-2.3)
Owsley et al. (2003)	365	Not Reported	**< .01**	T-Statistic	*t*(1, 360) = 8.24
Owsley et al. (2004)	338	Not Reported	**< .0001**	Not Reported	Not Reported
Stalvey & Owsley (2003)	365	Ix [*mean change* (SD): .58 (2.5)] Control [*mean change* (SD): -.33 (2.4)]	**< .001**	T-Statistic	*t*(1, 352) = 3.53
[*Community participation and use of alternative transportation*]					
Coxon et al. (2017) [Alternative Transportation]	365	Ix [*mean* (SE): 4.8 (.55) Control [*mean* (SE): 4.7 (.55)	.9	Raw group mean difference	.1 (95% CI = -1.4-1.6)
Coxon et al. (2017) [Community Participation]	366	Ix [*mean* (SE): 1.3(.17)] Control: [*mean* (SE): 1.4 (.17)]	.59	Raw group mean difference	.1 (95% CI = -.6-.3)
Coxon et al. (2017) [Socialization]	363	Ix [*mean* (SE): 32.4 (.53)] Control [*mean* (SE): 31.6 (.54)	.31	Raw group mean difference	.8 (95% CI = -.7-2.2)
Outcome: On-road driving performance					
[Behind-the-wheel performance]					
Education-based interventions					
Anstey et al. (2018) [Rate of improvement]	57	Ix [1.07] Control [.32]	.117	Standardized Association	$B_{(time*group)}$ = .75 (SE = .48)
Ashman et al. (1994)	25	Ix [*Mean difference* (%): 3.7] Control [*Mean difference* (%): -.4]	**.0113**	Not Reported	Not Reported
Bédard et al. (2004)	65	Ix [*mean change* (SD): 4.2 (7.11)] Control [*mean change* (SD): 3.46 (6.72)]	0.747	T-Statistic	*t*(63) = .32
Bédard et al. (2008) [Starting/stopping/backing]	18 (Winnipeg)	Ix [*mean change* (SD): -5.56 (15.90)] Control [*mean change* (SD): 1.67 (20.31)]	.472	F-Statistic	.55

Author, Year	Sample size (*n*) (Intervention + control)	Within group changes	Reported *p*-values	Type of Effect Reported	Effect Size Reported
	39 (Thunder Bay)	Ix [*mean change* (SD): -9.17 (14.68)] Control [*mean change* (SD): -3.81 (14.68)]	**.049**		4.16
Bédard et al. (2008) [Signal violation/ right of way/ inattention]	18 (Winnipeg)	Ix [*mean change* (SD): -4.44 (32.35)] Control [*mean change* (SD): -.56(26.98)]	.981	F-Statistic	.00
	39 (Thunder Bay)	Ix [*mean change* (SD): 1.39 (11.22)] Control [*mean change* (SD):.48 (10.60)]	.306		1.08
Bédard et al. (2008) [Moving along the roadway]	18 (Winnipeg)	Ix [*mean change* (SD): -18.89 (4.97)] Control [*mean change* (SD): -13.33 (37.33)]	**.037**	F-Statistic	5.23
	39 (Thunder Bay)	Ix [*mean change* (SD): -5.56 (8.20)] Control [*mean change* (SD): -1.90 (10.78)]	**.049**		4.15
Bédard et al. (2008) [Passing/ Speed]	18 (Winnipeg)	Ix [*mean change* (SD): -.56 (8.82)] Control [*mean change* (SD): -1.11 (20.58)]	.936	F-Statistic	.01
	39 (Thunder Bay)	Ix [*mean change* (SD): -2.78 (7.12)] Control [*mean change* (SD): -2.62 (9.5)]	.183		1.85
Bédard et al. (2008) [Turning]	18 (Winnipeg)	Ix [*mean change* (SD): -7.78 (24.89)] Control [*mean change* (SD): -10.00 (23.45)]	.572	F-Statistic	.33
	39 (Thunder Bay)	Ix [*mean change* (SD): -2.22 (8.08)] Control [*mean change* (SD): -3.10 (7.15)]	.643		.22
Lavallière et al. (2012)	22	Ix [*mean change* (%): 32.7] Control [*mean change* (%): 1.3]	**< .05**	F-Statistic	4.88
Marottoli, Van Ness, et al. (2007)	92	Ix [*least square mean change* (SE): 5.95] Control [*least square mean change* (SE): 3.08]	**.001**	Raw group mean difference	2.87
Porter (2013)	37	Not Reported	> .05	Not Reported	Not Reported
Sawula et al. (2018)	78	Ix [*Raw Mean Change* (95% CI) = -41.64 (-53.29, -26.21)] Ix2 [*Raw Mean Change* (95% CI) = -38.69 (-52.16, - 22.20)] Control [*Raw Mean Change* (95% CI) = -7.18 (- 14.26, -.11)]	**< .001**	F-Statistic	15.74
Physical exercise interventions					
Ashman et al. (1994)	26	Ix [*Mean difference* (%): 6.8] Control [*Mean difference* (%): -.4]	**.0069**	Not Reported	Not Reported
Ashman et al. (1994)	25	Ix [*Mean difference* (%): 8.7] Control [*Mean difference* (%): -.4]	**.011**	Not Reported	Not Reported
Marottoli, Allore, et al. (2007)	174	Ix [*least square mean change* (SE): -.4 (1.03)] Control [*least square mean change* (SE): -2.83 (1.12)]	**.032**	Least square mean difference	2.34 (SE = 1.12)
Ostrow et al. (1992)	32	Not Reported	**< .05**	F-Statistic	$F(2, 59) = 3.55$

Author, Year	Sample size (*n*) (Intervention + control)	Within group changes	Reported *p*-values	Type of Effect Reported	Effect Size Reported
<u>Cognitive training interventions</u>					
Ashman et al. (1994)	23	Ix [*Mean difference* (%): 7.7] Control [*Mean difference* (%): -.4]	**.0065**	Not Reported	Not Reported
Ashman et al. (1994)	25	Ix [*Mean difference* (%): 8.7] Control [*Mean difference* (%): -.4]	**.001**	Not Reported	Not Reported
Casutt et al. (2014)	54 (Ix I vs. Ix II)	Not Reported	**< .05**	Cohen's d	.48
Casutt et al. (2014)	54 (Ix I vs. Control)	Not Reported	< .11	Cohen's d	.35
Roenker et al. (2003) [Overall Improvement]	95	Not Reported	**<.001**	Eta-squared	.10
[*Simulator-based driving performance*]					
Rogé et al. (2014) [Useful visual field size]	31	Not Reported	**< .0001**	F-Statistic	*F*(1, 29) = 250.06
Rogé et al. (2014) [Visibility distance]	31	Not Reported	**.05**	F-Statistic	*F*(1, 27) = 4.19
[*MVC-related outcomes*]					
Ball et al. (2010) [*Relative risk over time*]	588 (Speed-of-Processing+ Control)	Ix [*At-fault crashes/ year*: .019] Control [*At-fault crashes/ year*: .035]	**< .05**	Relative Rate	.52 (95% CI = .31-.87)
	554 (Reasoning + Control)	Ix [*At-fault crashes/ year*: .023] Control [*At-fault crashes/ year*: .035]	**< .05**		.44 (95% CI = .24-.82)
	584 (Memory + Control)	Ix [*At-fault crashes/ year*: .030] Control [*At-fault crashes/ year*: .035]	**> .05**		.82 (95% CI) = .53 -1.27
Ball et al. (2010) [*Relative risk by mile driven]*	588 (Speed-of-Processing+ Control)	Ix [*At-fault crashes/ mile*: .00000362] Control [*At-fault crashes/ mile*: .00000628]	**< .05**	Relative Rate	.57 (95% CI = .34-.96)
	554 (Reasoning + Control)	Ix [*At-fault crashes/ mile*: .00000465] Control [*At-fault crashes/ mile*: .00000628]	**< .05**		.50 (95% CI = .27-.92)
	584 (Memory + Control)	Ix [*At-fault crashes/ mile*: .00000587] Control [*At-fault crashes/ mile*: .00000628]	**> .05**		.93 (95% CI = .6-1.45)
Owsley et al. (2004) [MVC per mile driven]	338	Not Reported		Relative Rate	1.08 (95% CI = .71-1.64)
Owsley et al. (2004) [MVC per years of active driving]	338	Not Reported		Relative Rate	1.40 (95% CI = .92-2.12)
[*Driving Exposure*]					
Coxon et al. (2017)	366	Not Reported	.57	Raw group mean difference	-5.5 (95% CI = -24.5-13.5)

CI = Confidence Interval; Ix = Intervention Group; MVC = Motor Vehicle Collision; SD = Standard Deviation; SE = Standard Error
*Effect sizes are reported by outcome; where RCTs reported values for sub-outcomes, these are listed in [ ].

Supplementary File

Narrative summary of interventions examined by outcome

Knowledge of road safety

Classroom-based group education was found to significantly improve knowledge of road safety and vehicle operation for older drivers (Jones et al., 2012; Marottoli, Van Ness, et al., 2007). Jones and colleagues (2012) compared a structured group-based program (4 mandatory sessions on knowledge related to driving safety and CarFit) to an unstructured, less intensive group format (1 mandatory session and up to 2 optional sessions, including the CarFit session). Participants in their intervention group scored significantly higher on a test of road safety knowledge compared to controls (Mean Group Difference = 2.83, $p < .01$, $n = 47$). However, this difference was not maintained at a 6-month follow-up. Marottoli, Van Ness and colleagues (2007) found participants who received feedback on their driving performance in addition to classroom-based group education performed significantly better (Least Squares Mean Change = 3.44, $p < .001$, $n = 92$) on a knowledge test than those who received only the classroom-based group education. Other studies also described improvements in road safety knowledge post-intervention consisting of classroom-based group education and in-vehicle training ($p < .001$) (Bédard et al., 2008; Sawula et al., 2018). However, neither study conducted between group comparisons for this outcome.

Self-perceived behind-the-wheel skills and behaviours

Thirteen studies assessed self-perceived behind-the-wheel skills and behaviours. Eight studies used standardized self-report outcome measures and five used measures authors developed for the respective study. Standardized measures included the Mobility Driving Habits Questionnaire (MDHQ; Owsley, Stalvey, Wells, & Sloane, 1999), Driving Perception and Practice Questionnaire (DPPQ; Stalvey & Owsley, 2003), and Keele Assessment of Participation (KAP; Wilkie, Peat, Thomas, Hooper, & Croft, 2005). Outcomes tracked using self-report measures included: driving status (Edwards, Delahunt, et al., 2009; Owsley et al., 2004, 2003; Ross et al., 2017), driving exposure (Anstey et al., 2018; Edwards, Myers, et al., 2009; Ostrow et al., 1992; Owsley et al., 2004; Ross et al., 2016), perceived driving difficulty (Edwards, Myers, et al., 2009; Owsley et al., 2004, 2003), attitudes towards driving and use of self-regulation strategies (Coxon et al., 2017; Owsley et al., 2004, 2003; Tuokko et al., 2015) use of alternative transportation and community participation (Coxon et al., 2017).

Eight studies used the MDHQ or modified versions of this measure. The MDHQ is a valid and reliable self-report tool (Owsley et al., 1999) that includes the following sub-sections: *driving status*, *driving exposure* (e.g., frequency of trips, distance driven), *driving difficulty* (e.g., level of difficulty assigned to driving situations; 1 = *no difficulty* to 4 = *extreme difficulty*), and *driving space* (e.g., list of destinations ranging from the respondent's own property to beyond their geographic region). Outcomes are reported as composite scores (i.e., scores of all sub-sections combined). Results from two studies that did not use the MDHQ have been described alongside similar outcomes from the MDHQ (e.g., driving exposure, level of driving difficulty).

Jones and colleagues (2011) captured domains, such as mileage, driving exposure and driving difficulty (similar to those in the MDHQ), in a non-standardized questionnaire developed for their study. Results from their questionnaire found no differences (p's between .95-.73) between those who participated in classroom-based group education focused on road knowledge (n = 38) and those who did not receive such education (n = 39).

Self-reported Driving Status

Only two RCTs included in this review examined their intervention with respect to changes in active licensure or driving status (e.g., currently driving vs. given up driving) (Edwards, Delahunt, et al., 2009; Ross et al., 2017). Both Edwards, Delahunt and colleagues (2009) and Ross and colleagues (2017) modified the MDHQ to track changes in self-reported driving status after participation in cognitive training at 3- and 10- year follow-ups. Using pooled data from the SKILL and ACTIVE trials, Edwards, Delahunt and colleagues (2009) found older drivers in their intervention group were 40% less likely to give up driving compared to controls [Hazard Ratio (HR) = .568, 95% CI = .356-.995, p = .048]. Ross and colleagues (2017) analyzed data from the ACTIVE trial only. They found drivers who received approximately 10 sessions of speed-of-processing training that adapted task difficulty to participant abilities were half as likely (49%) to give up their driver licenses (HR = .51, 95% CI, = .24-.86, n = 324) compared to controls. Those who underwent more than 10 training sessions were 70% less likely to give up driving (HR = .30, 95% CI, .011-.082, p < .05, n = 252) (Ross et al., 2017). Modifications to the MDHQ were also made in the *driving status* construct by Owsley and colleagues (2003), who reported driving status as *driving dependency* (i.e., dependency on others to drive). Individuals that received one-on-one education tailored to promote self-regulatory driving practices and usual care from an optometrist did not differ in their dependence on other drivers 6-months after the intervention from those who only received usual care (t (1, 361) = 1.44, p = .14, n = 365).

Self-reported Driving Exposure

Of the 33 included studies, three RCTs tracked self-reported *driving mileage*; one used the MDHQ (Owsley et al., 2004, 2003) and two asked participants to log their distance driven and locations visited (Anstey et al., 2018; Ostrow et al., 1992). Owsley and colleagues (2004, 2003) found self-reported trips per week significantly decreased at the six- [t(1, 361) = 2.26, p< .02, n = 364] and 24-month (p < .02) follow-up among older drivers who had received tailored one-on-one education of self-regulation in addition to usual care when compared to controls. Ostrow and colleagues (1992) found no difference in self-reported days driven per week [F(7, 232) = 1.00, p < .5, n = 32] or driving mileage [F(7, 232) = 1.00, p<.5, n = 32] between participants who received a physical training intervention to controls. Similarly, Anstey and colleagues (2018) found no difference (p > .1) in self-reported mileage by those who underwent on-road training by a driving instructor and occupational therapist following classroom-based group-education [*mean*

(SD) = 1175.5 (566.3), *n* = 29] and those who only received the group-education [*mean* (SD) = 979.7 (585.5), *n* = 28].

Edwards, Myers and colleagues (2009) modified the MDHQ to evaluate self-reported exposure to challenging driving conditions. In their study, older drivers at high-risk of mobility decline (determined by scores on a cognitive assessment) received adaptive speed-of-processing training. They found this group [*n* = 66; *mean age (SD)* = 74.13 (4.91)] did not differ in their level of driving exposure to a comparator (low-risk of cognitive decline) control group (*n* = 366; *mean age (SD)* = 72.08 (4.98)) up to 3 years post-training (*p* > .05). A second control group, those at high-risk of cognitive decline [*n* = 68; *mean age (SD)* = 74.52 (5.69)] that received a placebo intervention (social and computer contact), demonstrated a decline in driving exposure compared to the intervention and low-risk reference groups (*p* < .015). Ross and colleagues (2016), also using this modified version of the MDHQ, found those that received adaptive speed-of-processing cognitive training in higher doses reported driving more often compared to study controls and participants receiving lower doses (est.= 0.019 [*SE* = .008], 95% CI = .004, .033, *p* < .05, *d* = .6).

Self-perceived Driving Difficulty

Only three studies tracked the impact of interventions on perceived *driving difficulty*. Edwards, Myers and colleagues (2009) found a significant group by time effect on the three-item MDHQ composite for *driving difficulty* [F(2, 493) = 11.99, *p* <.001, *n* = 500], but not on the five-item composite [F (2, 493) = 1.83, *p* = .161, *n* = 500]. Compared to the low-risk reference group, pairwise comparisons indicated that both the high-risk intervention group receiving adaptive speed-of-processing training (*p* = .004) and the high-risk control group (*p* < .015) declined over three years, suggesting their increased difficulty with driving. Owsley and colleagues (2004, 2003) modified the MDHQ *driving difficulty* composite to assess participants' level of *driving avoidance* of hazardous situations. Study participants who received tailored one-on-one education on self-regulation practices, alongside usual care, reported avoiding such situations significantly more than those who only received usual care with an optometrist at six- [*t*(1, 360) = 6.21, *p* < .01, *n* = 365] and 24-month (*p* < .0001).

In their case-control pilot trial, Caragata and colleagues (2009) elicited intervention participants (*n* = 19) general feedback that suggested a generic physical exercise program improve driving tasks (e.g., visual scanning), as compared to controls (*n* = 5) who reported no change overall.

Self-perceived impact on Driving Space

Two studies examined the effectiveness of one-on-one education on MDHQ *driving space* (i.e., zones people drove beyond their home). Coxon and colleagues (2017) found no change in restrictions to *driving space* beyond their local communities between those that received tailored one-on-one education from an occupational therapist on self-regulatory driving practices compared to no-intervention controls [Odds Ratio (OR) = 1.04, 95% CI = .65-1.66, *p* = .88, *n* = 380]. Alternatively, Owsley and colleagues (2003) found individuals who received the tailored education on self-regulatory driving practices alongside usual care from an optometrist reported significant reduction in their level of driving space, as described in the *driving exposure* section.

Edwards, Myers and colleagues (2009) found significant group by time interactions on *driving space* [$F(2, 493) = 3.35$, $p = .036$, $n = 500$], specifically, that the high-risk control group reduced the distance they ventured from home compared to the low-risk reference group ($p < .015$). Individuals at high-risk of cognitive decline and receiving adaptive speed-of-processing training were not found be different from the low-risk reference group. No significant differences ($p > .05$) between intervention groups (i.e., those receiving only 10 or more than 10 sessions of adaptive speed-of-processing training) were found in *driving space* by Ross and colleagues (2016).

Attitudes towards driving and use of self-regulatory strategies

Results from the DPPQ were described by three sub-studies of the same trial (Owsley et al., 2004, 2003; Stalvey & Owsley, 2003). This trial evaluated attitudes towards driving and self-regulatory practices. Participants who received individualized self-regulatory education reported using self-regulation strategies (e.g., avoiding night-time or rush-hour driving) significantly more than controls at six- [$t(1, 350) = 8.24$, $p < .01$, $n = 365$] (Owsley et al., 2003), and 24-month ($p < .0001$)(Owsley et al., 2004) follow-up. Stalvey & Owsley (2003) also indicated intervention group participants reported a higher number of perceived benefits to self-regulation [$t(1, 352) = 3.53$, $p < .001$, $n = 365$]. Participants who received self-regulatory education reported no difference in their attitudes towards driver safety compared to controls [$t(1, 356) = 1.0$, $p = .31$, $n = 365$] (Owsley et al., 2003).

Coxon and colleagues (2017) found that participants who received tailored one-on-one self-regulatory education were significantly more likely (OR = 1.6, 95% CI = 1.1 – 2.3, $p = .02$, $n = 380$) to adopt self-regulation strategies, compared to controls. Tuokko and colleagues (2015) developed a questionnaire that covered four scales (attitude, consciousness raising, perceived control, and intention) based on theories of behaviour change. They did not identify any significant differences in any of the subscales between individuals that viewed a play on driver safety and matched controls who reviewed material on driver safety.

Self-reported community participation and use of transportation

Coxon and colleagues (2017) reported no within- or between-group differences in participants' self-reported use of alternative transportation (Between-group difference = .1, 95% CI = -1.4-1.6, $p = .9$, $n= 380$), community participation (Between-group difference = -.1, 95% CI = -0.6-0.3, $p = .59$, $n= 380$) and socialization (Between-group difference = .8, 95% CI = -.7-2.2, $p = .31$, $n= 380$) at 12-months, following two sessions of one-on-one self-regulation education provided by an occupational therapist compared to no intervention.

Objective measures of driving performance

In this review, objective measures of driving performance included: 1) behind-the-wheel errors, as assessed during on-road evaluation; 2) behind-the-wheel errors, as assessed in a driving simulator; 3) MVC-related statistics; and 4) naturalistic driving exposure.

On-road driving performance

There were 15 studies that used on-road evaluations to examine the effectiveness of their respective intervention. Seven evaluations were designed in accordance with those administered by their respective transportation authority, including Ontario, Canada (Bédard et al., 2004; Sawula et al., 2018), Manitoba, Canada (Bédard et al., 2008; Porter, 2013), Connecticut, United States (Marottoli, Allore, et al., 2007; Marottoli, Van Ness, et al., 2007), and Zurich, Switzerland (Casutt et al., 2014). The remaining eight studies used evaluations that had been specifically developed for research purposes. On-road evaluations were scored by a driving instructor during the drive or by trained evaluators viewing videos from in-vehicle recording devices of participant drives.

Education-based interventions

Among older drivers' who participated in only classroom-based programming, Ashman and colleagues (1994) found on-road performance significantly improved (p = .0113, n = 25). Neither Bédard and colleagues (2004) [$t(63) = .32$, p = .747, n = 65] nor Porter (2013) found significant differences (p > .05) when comparing those that received classroom-based education to no intervention.

Interventions where classroom-based group education preceded tailored on-road training sessions delivered by a driving instructor were effective in improving driving performance (Bédard et al., 2008; Marottoli, Van Ness, et al., 2007). For example, Bédard and colleagues (2008) found this training significantly reduced performance on specific maneuvers such as behind-the-wheel errors [e.g., F-statistic$_{\text{(Winnipeg)}}$ = 5.23, p = .037, n = 18; F-statistic$_{\text{(Thunder Bay)}}$= 4.15, p = .049, n = 39] and starting/ stopping/ backing [F-statistic$_{\text{(Thunder Bay)}}$= 4.16, p = .049, n = 39]). Similarly, Marottoli, Van Ness, and colleagues (2007) found participants who received tailored feedback by a driving instructor significantly improved their on-road performance compared to the control group who only received one-on-one education on home safety (Least Squares Mean Change = 2.87, p = .001, n = 92).

Anstey and colleagues (2018) compared the effects of two interventions on driving performance: 1) classroom-based group education (control group); 2) classroom-based group education combined with tailored feedback during an on-road drive and participants' viewing of videos of their own pre-assessment drives (intervention group). The intervention group demonstrated a significant within-group reduction in critical/ dangerous on-road errors (Incident Rate Ratio (IRR) = .53, Standard Error (SE) = 13, p = .008, n = 29). However, between-group differences in rate of improvement in driver safety ratings were not significant ($\beta_{time*group}$ = .75, SE = .48, p = .117, n = 57) (Anstey et al., 2018). Sawula and colleagues (2018) found a significant difference [$F_{(2, 74)}$ = 15.74, p < .001, n = 78] in on-road performance between three treatment arms: 1) attendees of a classroom-based group education program (i.e., Basic Training; BT); 2) BT + feedback on videos of their own pre-assessment drives and in-vehicle training with an instructor (i.e., On-Road; OR); and 3) BT + OR + feedback on simulated driving practice (i.e., Simulated Training; ST). Post-hoc pairwise comparisons identified that the significant difference in on-road performance was between the BT-only group and the two intervention groups. There was no difference between intervention groups, indicating both intervention groups improved.

Lavallière and colleagues (2012) provided participants in the experimental group with feedback on their simulated driving training following classroom-based education, where those in the control group did not receive such feedback. Participants in the experimental group improved the frequency with which they conducted *blind spot verification* (32.7% improvement) compared to controls (1.3% improvement) [$F(2, 38) = 4.88$, $p < .05$, $n = 22$]. In their case-control study, Romoser and Fisher (2009) found driving improved (i.e., secondary looks when making left turns) among those who received tailored feedback following on-road and simulator-based training alongside practice in a driving simulator, compared to no intervention [$F(1,22) = 11.83$, $p < .005$, $n = 36$] or group-based classroom instruction on road safety [$F(1,22) = 13.11$, $p < .005$, $n = 36$] (Romoser & Fisher, 2009). Romoser (2013) conducted a 2-year within-group follow up of the 2009 study but did not report between-group comparisons. Porter (2013) found on-road performance did not differ significantly between those who received tailored feedback from a driving instructor on videos of their own drives alongside classroom-based education ($n = 17$) from those that only received classroom-based instruction ($n = 18$), or received no intervention ($n = 19$). However, those who received tailored feedback were the only group to demonstrate significant within-group reduction of driving errors ($p < .05$) (Porter, 2013).

Jacobs and colleagues (1997) found significant between-group differences [$F(2, 18) = 10.38$, $p = 0.05$] when they compared post-test scores of on-road performance across three groups: 1) those receiving simulator training (no tailoring) combined with generic educational videos of simulated driving scenarios (n = 7); 2) to those watching only educational videos (n = 6); 3) or those receiving no intervention (n = 7). Neither pre-test scores nor post-hoc pairwise comparisons of post-test scores were reported.

Physical exercise interventions

Compared to no intervention, Ashman and colleagues (1994) found on-road performance significantly improved following a pre-planned daily physical exercise regimen ($p = .0069$, $n = 26$), and also when physical exercise was combined with classroom-based group education ($p = .011$, $n = 25$). Ostrow and colleagues (1992) found that exercise programs tailored to the specific physical abilities of participants significantly improved driving tasks of observing their environment (e.g., turning one's head to scan for traffic at intersections) [$F(2, 59) = 3.62$, $p < .05$, $n = 32$]. However, the no-intervention control significantly improved their vehicle handling abilities [$F(2, 59) = 3.55$, $p < .05$, $n = 32$], compared to the intervention group (Ostrow et al., 1992). Marottoli, Allore, and colleagues (2007) also provided older drivers with a physical exercise regimen tailored to participants' specific needs alongside generic modules on home safety ($n = 84$) compared to those who only received these modules ($n = 90$). The intervention group improved by a least square mean change of 2.34 points (SE = 1.12, $p = .032$) higher on the on-road evaluation than the control group (which actually demonstrated a significant decrease over time) (Marottoli, Allore, et al., 2007).

Cognitive training interventions

Ashman and colleagues (1994) found participants who performed pen-and-paper perceptual activities performed significantly better on a standardized on-road evaluation, compared to those that received no intervention ($p = .0065$, $n = 23$). The highest mean rank of differences in driving performance (following pairwise comparison of 5 treatment arms) was achieved between older drivers that performed the perceptual exercises alongside attending a classroom-based education session to those that received no intervention ($p = 0.001$; $n = 25$) (Ashman et al., 1994). Casutt and colleagues (2014) compared attention training ($n = 23$) to simulator-based driver training ($n = 31$), or no intervention (n = 23). Although participants who received simulator-based training improved their overall on-road driving performance compared to those in the attention-training group [$F(1, 74) = 2.86$, $p < .05$, $d = .48$], they did not improve compared to those that received no intervention [$F(1, 74) = 1.59$, $p = .11$, $d = .35$]. Improvement in the control group was greater than either intervention arm in the *lane behaviour* sub-measure [$t_{(74)} = -1.96$, $p < .05$, 1-tailed, $d = .54$]. Both interventions were only superior to the control group in two sub-measures: *change of direction* [$t_{(74)} = 2.24$, $p < 0.05$, 1-tailed, $d = .56$], and *district dependent behaviour* (i.e., driving in urban vs. rural settings) [$t_{(74)} = 2.62$, $p < .05$, 1-tailed, $d = .68$]. Roenker and colleagues (2003) also identified a significant improvement in overall driving performance [$F(2, 184) = 9.85$, $p < .001$, $MSE = .32$, eta$^2 = .07$] by participants in the high risk treatment arm and the low risk reference group. However, improvements in driving performance after the intervention and at 18-month follow up were not significant for those receiving adaptive computer-based, speed-of-processing training (n = 48), compared to those who received generic simulated driving practice and generic road safety education (n = 22) or those receiving no intervention at all (n = 25).

Simulator-based driving performance

Romoser and Fisher (2009) found older drivers who received feedback on their on-road and simulated drives performed more secondary looks while making a left turn during a subsequent simulated drive, compared to those who did not receive such feedback [$F_{(1, 34)} = 18.89$, $p < .001$]. They also found a significant difference between the feedback group and those that only received classroom-based group education [$F_{(1,34)} = 5.87$, $p < .05$] (Romoser & Fisher, 2009). Rogé and colleagues (2014) provided participants with feedback (i.e., an auditory tone during the driving task) indicating correct or incorrect detection of vulnerable road users (e.g., pedestrians, cyclists). Significant improvement was observed among those who received such adaptive training, compared to those that received non-adaptive training (i.e., no auditory feedback) of specific simulated driving tasks on outcomes of *useful visual field size* [$F(1, 29) = 250.06$, $p < .0001$] and *visibility distance* [$F(1, 27) = 4.19$, $p = .05$] during simulated driving (Rogé et al., 2014). Cuenen and colleagues (2016) did not find differences in improvement of simulated driving behaviours (e.g., *driving speed* or *complete stop at stop sign*) following working memory training tailored to participants' abilities, compared to those who received training that was not tailored.

MVCs

Nasvadi and Vavrik (2007) found no significant differences in crash rates of those who participated in classroom-based education compared to matched controls. Rates of MVCs did not change for the period where classroom-based group education was combined with feedback of driving performance after participating in an on-road driving test (Ichikawa et al., 2015). Conversely, Vanlaar and colleagues (2016) found a significant decrease in collision involvement (OR .91, p = .03) for drivers aged 80 and older following their participation in a government-mandated group-based educational program, compared to their age-matched counterparts in other jurisdictions that did not mandate such education.

At a 2-year follow-up, Owsley and colleagues (2004) did not find between-group differences in MVC involvement data from vehicle licensing records for those receiving one-on-one self-regulation instruction combined with usual care, compared to those receiving usual care alone. Additionally, neither the rate of MVC involvement per mile driven [RR = 1.08, 95% CI = 0.71-1.64, n = 338] nor per years of active driving prior to death or driving retirement [RR = 1.40, 95% CI = 0.92-2.12] were found to be significant (Owsley et al., 2004).

Ball and colleagues (2010) reported significant lower rates of at-fault MVCs over time following adaptive speed-of-processing training [RR = 0.52, 95% CI = .31-.87, n = 588] and reasoning training [RR = .44 (95% CI = .24-.82), n = 554], and per mile driven following adaptive speed-of-processing training [RR = .57 (95% CI = .34-.96), n = 588] and reasoning training [RR = .50 (95% CI = .27-.92), n = 554]when demographic and health characteristics (i.e., age, gender, race, education, location, visual acuity, health, depression and mental status) were adjusted for.

Driving Exposure

Coxon and colleagues (2017) did not find any significant difference (Between group difference = -5.5km, 95% CI = -24.5-13.5, p = .57, n = 366) in distance driven, logged by a global positioning device (GPS) over 12 months of participants' daily driving, when comparing older drivers who received instruction on self-regulatory practices compared to a control group.

Chapter Three: Older adults' motivations for participating in a 'tune-up' of their driving skills: A multi-stakeholder analysis

Preface

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Title Page

Older adults' motivations for participating in a 'tune-up' of their driving skills: A multi-stakeholder analysis

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Abstract

Driver training has been identified as a way to keep older adults safe behind-the-wheel for longer, yet, there is limited evidence describing factors that can influence their willingness to participate in such training. Focus groups with community-dwelling older drivers (n=23; 70-90 years) alongside semi-structured interviews with driving instructors (n=6) and clinicians (n=5) were conducted to identify these factors. Qualitative descriptive analyses highlighted how self-awareness of behind-the-wheel abilities in later life can have a major influence on participation in older driver training alongside encouragement from family and friends. Collision-involvement and near-misses prompted participants to reflect on their abilities and openness to feedback. Participant preferences for learning contexts that use a strengths-based approach and validate the driving experience of older drivers alongside providing formative feedback on behind-the-wheel performance were raised. The heterogeneity of the aging population should be considered when designing driver training initiatives aimed at promoting their road safety and community mobility.

Keywords: older drivers, driving behaviour, training, focus group, interview

Introduction

Adults aged 65 years and older want to drive, need to drive, and live in communities where driving is both valued and necessary for mobility and social engagement (Miller, 2017; Mollenkopf et al., 2002; Nordbakke & Schwanen, 2015; Turcotte, 2012). However, this age group has one of the highest crash risks when distance driven is considered and are more likely to be injured or killed (Regev, Rolison, & Moutari, 2018). Their heightened risk has been attributed to a number of factors, including the onset of medical conditions and associated functional declines (Marshall et al., 2013), lower on-road exposure (Langford, Methorst, & Hakamies-Blomqvist, 2006), increased errors in behind-the-wheel observations and judgement (Cicchino & McCartt, 2015), as well as lower confidence when driving (Myers, Paradis, & Blanchard, 2008). Such factors have also been linked to relinquishing one's driver's license in later life (Ragland, Satariano, & MacLeod, 2005).

When the ability to drive is questioned for medical reasons or otherwise, older adults can feel like their autonomy is being threatened and fear becoming a burden on family and friends (Laliberte Rudman, Friedland, Chipman, & Sciortino, 2006). Raising the issue of medical fitness-to-drive can lead to an emotionally charged exchange between older drivers and their loved ones, as well as with healthcare professionals (Betz, Jones, Petroff, & Schwartz, 2013; Caragata, Wister, & Mitchell, 2019; Friedland, Rudman, Chipman, & Steen, 2006; Söllner & Florack, 2019). Knowing they might lose their license can heighten concern about their own behind-the-wheel performance (Allen, Beck, & Zanjani, 2019; Hassan, King, & Watt, 2015; Stutts & Wilkins, 2003). Laliberte

Rudman et al. (2006) found such concerns were amplified even among older adults who were deemed medically fit-to-drive. They referred to this older driver group as the 'well-elderly.' Given the importance of driving to functional mobility and community engagement in later life, determining the most effective approaches to keep older adults safe behind-the-wheel for as long as possible is needed (Hassan et al., 2015; Laliberte Rudman et al., 2006; Stutts & Wilkins, 2003).

While some older adults voluntarily seek driver education and training programs offered at seniors' clubs or contact a local driving school for instruction (Hassan et al., 2015), the impact of such programs on their behind-the-wheel behaviour is unclear. Our recent systematic review highlighted the variability in approaches to older driver training aimed at improving road safety knowledge, self-perceptions of driving ability, and on-road performance (Sangrar et al., 2019). According to Keskinen (2014), for any driving-related program to be successful with regard to changing behind-the-wheel behaviour, the specific skills, motivations and interests of older drivers should be considered in the design of the program.

Multiple studies have found that older drivers view participation in training programs as a means to maintain their licensure (Hassan et al., 2015; Hawley, Smith, & Goodwin, 2017; Kua, Korner-Bitensky, & Desrosiers, 2007; Laliberte Rudman et al., 2006; Musselwhite & Haddad, 2010). For example, Hawley et al. (2017) asked older drivers in their study about their motivations for engaging in classroom-based driver education training. While the focus of their study was on evaluating a specific training approach, older drivers indicated a host of reasons for their participation, including wanting to update their knowledge of traffic laws, improving behind-the-wheel skills, and determining if they were still fit to drive. From their findings, the authors highlighted a paradox; older drivers who were competent behind-the-wheel were more likely to attend this training than those who actually needed and could benefit most from the program. Unfortunately, the perspectives of those who deliver or recommend such training (e.g., driving instructors, clinicians) were not considered. Exploring such divergent perspectives with regard to motivations for participation in older driver training can inform the development of new approaches to older driver training or could improve existing programs aimed at the aging population.

The current study sought input from a range of stakeholders (i.e., older drivers, driving instructors [DI], occupational therapists [OT]) to gain both breadth and depth in their respective perceptions of older driver training programs with the goal of informing the design of such a program. The specific research question guiding this exploratory qualitative study was: *What factors can influence older adults' participation in driver training?* In accordance with the aim of this study, participants were asked to share their recommendations for the design and delivery of this training.

Methods

Participant Recruitment

Purposive and snowball sampling strategies were used to recruit stakeholders (i.e., older drivers, driving instructors and occupational therapists) in this descriptive qualitative study (Sandelowski, 2000). Eligibility criteria for older adults recruited from a database of research volunteers: age 65+ years, valid driver's license, drove at least once per week, and spoke English. Participants were excluded if a medical professional had informed them that they were no longer fit-to-drive as the focus of the project was on maintaining one's driving ability. To recruit driving instructors and occupational therapists to obtain their perspectives on the barriers and facilitators of program development and delivery, a brief description of the study and an invitation to participate were emailed to colleagues within the authors' professional networks. Driving instructors were eligible to participate if they had experience training older drivers and spoke English. Occupational therapists were eligible to participate if they spoke English and had experience providing health-related education to older adults in primary care settings (e.g., educational programs on driving retirement, fall prevention, or healthy aging). Occupational therapists were excluded if their clinical expertise was solely focused on specialized driving evaluations for medically at-risk drivers which do not represent the target population who are generally healthy older adults. All participants were encouraged to share the authors' contact information with others who might be interested in the study. Recruitment efforts continued until data saturation was achieved. Older drivers were reimbursed for parking expenses when attending focus group sessions and a letter of gratitude was sent to participating professionals after their interview. The Hamilton integrated Research Ethics Board approved this study (HiREB Project # 3005). The present study falls within a larger mixed-methods study aimed at designing a driver training program to improve behind-the-wheel performance of older drivers.

Data Collection

Focus groups of 5-8 older drivers were conducted in a classroom setting at McMaster University, Hamilton, Canada, lasting between 90 – 120 minutes. The first session was co-facilitated by two study investigators (BV & RS), and subsequent sessions were led by one investigator (RS), a research assistant (JM), and an older driver expert-advisor. The role of the expert-advisor was to assist the investigators with clarifying the focus group protocol and interview guide, co-facilitate the groups, and discuss their observations, for which they received training from the first author. At the beginning of each group, the investigators provided a brief overview and rationale for the study. Following each session, co-facilitators met to reflect on their observations and emerging ideas. Concurrent to the focus groups, the first author also conducted 1-1.5-hour semi-structured telephone interviews with each driving instructor (n = 6) and occupational therapist (n = 5). A single driving instructor opted to be interviewed in-person at the research institution. Prior to their scheduled interviews, participants were provided with detailed information letters and consent forms by email or mail, as preferred.

A semi-structured interview guide was developed using existing evidence on driver training (Hassan et al., 2015; Hawley et al., 2017; Kua, Korner-Bitensky, & Desrosiers, 2007), as well as other health-related programs aimed at older adults (e.g., fall prevention; see Yardley, Donovan-Hall, Francis, & Todd, 2006). Questions directed at each stakeholder group were tailored based on input from study partners (e.g., older driver expert-advisor). **Table 1** provides an example of the topics addressed alongside sample questions and probes for the older adult focus groups. Each guide was refined between interviews based on concurrent data analyses.

All focus groups and interviews were audio recorded and transcribed verbatim by a professional transcriptionist. Transcripts were checked for accuracy by the interviewers. To maintain participant confidentiality, pseudonyms were used for focus group participants and participant identification numbers for service delivery providers.

Table 1 Outline of discussion topics, sample questions and probes for older adult focus groups

Focus Group Interview Guide
Introduction
[Presentation on study purpose]
Past and present driving experiences
1. We know the ability to drive is important. Briefly describe the importance of driving to you.
2. Can you share some strategies that you use to keep yourself safe behind-the-wheel?
3. Have you noticed changes in your driving skills?
a. What is different about your driving today than when you were younger?
b. Why do you think your skills have changed?
c. Have you taken any action to address these changes?
Exploring the design of an older driver refresher program
4. Evidence suggests that training programs improve driving skills and keep people safer behind-the-wheel. Under what conditions would you seek such a program?
a. Would you voluntarily take a driving lesson?
b. Would you attend an in-class education session?
5. What advice would you want to help you improve your driving skills today?
Closing
6. If the Minister of Transportation told you that they were thinking of implementing a training program for older drivers in an effort to improve road safety and asked for your opinion on what it should include – what would you say to the Minister is the most important?

Data Analyses

Directed content analysis (Hsieh & Shannon, 2005) was used to examine the data. A framework for designing behaviour change interventions (see Bartholomew et al., 2016) informed the development of a preliminary coding scheme for the analysis. Two investigators (RS & JM) independently familiarized themselves with the audio recordings, transcripts and field notes in preparation for coding. Following line-by-line analysis of the first interview with each stakeholder group, sub-codes were generated to populate the preliminary coding framework. Any discrepancies between the coders were discussed and a refined version of the framework was then used to analyze the next set of transcripts using QSR International's NVivo 11 Software 2015. A constant-comparative method was used to further refine the framework, with input from the older driver expert-advisor. When no new information emerged, the investigators determined data saturation had been achieved. The final coding framework was audited by another investigator (BV) who was not directly involved in data collection or coding. To conduct member-checking, participants were provided with lay summaries of study findings. Feedback on this summary was elicited from each stakeholder group via email or telephone conversations and incorporated into the framework. Themes described in the present study were selected from relevant categories within the broader coding framework. Trustworthiness of the data was ensured through verbatim transcription, iterative review of the coding framework, and an audit trail of decisions made during analysis.

Results

Older drivers (n = 23) who participated in the focus groups were between 70 to 90 years (*Mean age (SD)* = 79.6 (±5.2); 12 were women and 11 were men). Of the six driving instructors, 2 were female. All occupational therapists were female and employed in primary care settings where they addressed driving and community mobility, as part of their general practice with older adults. From the data, emergent themes were divided into two major categories: 1) factors that motivate older adults to 'sign up' for driver training and, 2) considerations for the design and delivery of such training. Themes are presented using illustrative quotes.

Factors that motivate older drivers to 'sign-up' for driver training

'I've always been a careful driver:' Level of insight or awareness of one's current driving ability

When older drivers in the focus groups were asked about their current driving ability, many were quick to point out their 'clean' driving records. They attributed their ability to stay safe behind-the-wheel to their training as a novice driver. Tom (*age 85*) shared the following: "…when I started driving at 15, I was trained that if I had to hit the brakes, the first thing I did was look in the rear-view mirror." In fact, some older drivers described how their behind-the-wheel performance was superior to that of others on the roadway: "I've always been a careful driver. I always stop at stop signs. I don't do right hand turns on red. Maybe I'm a pain in the butt, I don't know, because…I seem to be the exception" (*Robert, age 71*). Another participant, Ned (*age 90*) shared how he responded to being tailgated: "…irritate them by leaving bigger and bigger spaces ahead, so they get closer and closer, so that space gets bigger and bigger, because I don't want to be rear-ended." Ivy (*age 80*) ignored others on the roadway by not "looking [in the rear-view mirror] because I'm figuring, no, I'm not going to worry about him [the other driver]. He [the driver] can see me and if I slow down, he's going to have to slow down."

Driving instructors viewed overconfidence in one's own behind-the-wheel abilities as one of the primary reasons why many older drivers do not seek out training at this life stage: "they rationalize what they do [when driving] and things they know shouldn't be done…it's a strange phenomenon in how they point the finger quickly at other people but they are not so quick to point the finger at themselves" (*DI04, male*). Another instructor attributed poor self-awareness to a discrepancy between perceived and actual on-road performance:

> [Older] people will say to me, "I don't like when other drivers don't signal. I'm one of those people who always puts my signal on," and then they make three turns in a row with no signal. They are not aware – and when you say to them, "You need to signal for your turns," they say, "I do." And I don't want to be the person to say to them, "Well as a matter of fact, you don't." (*DI01, female*)

Occupational therapists who were interviewed also found many older adults in their practice were not willing to admit deficiencies in their behind-the-wheel abilities, as one clinician explained, "there is a set of the [aging] population, or a group of the population, in terms of their readiness for change, they're just not there yet" (*OT02*).

'Sit up and take notice:' Critical events that indicate improvement in driving skills are needed

Some older drivers in the study recognized areas for improvement in their driving. For example, Alicia (*age 78*) reflected on changes to her behind-the-wheel performance over the years: "I have bad habits, I drive over the speed limit all the time and I have my hands down at the bottom not up here [places hands at 9 and 3 O'clock] because I'm relaxed." For other participants, such changes only became apparent after experiencing an adverse event, such as an at-fault collision or 'near miss':

> I think the typical embarrassing situation for me, and I'll bet for most of us, is merging into traffic when someone was in our blind spot. We turn our heads, we are sure there is nobody there, but there is, and you pull out and you get a real loud honk behind you, and you're embarrassed as hell. (*Peter, age 80*)

Other examples of near misses included: “bumping a pedestrian” (*Robert, age 71*), or “drifting out of their lane” (*Russell, age 82*). For Samantha (*age 83*), nearly colliding with a motorcyclist in her blind spot made her “sit up and take notice.” Such events were seen as a way to open up a discussions about driver training: “We think we have all the necessary skills when we don’t, and I think we need a wake-up call from time to time…admitting you’re not up to scratch, not as good as you once were” (Robert, *age 71*).

Older drivers described how changes in their driving ability were reflections of changes in their health and physical functioning. When such changes warranted conversations with a family member, this interaction was viewed as a critical event: “their children are recommending they do a couple of lessons” (*DI03, female*). For service delivery providers, making links between an individual’s age and/or health-related issues with potential or observed problems behind-the-wheel prompted conversations about driving. For example, driving instructors cited the impact of visual problems on the ability to scan the road environment. An occupational therapist described how she analyzed health impairments in relation to various elements of the driving task: “…so we would look at difficulty getting in and out of the vehicle, difficulty seeing over the dashboard, was it around range of motion to shoulder check, was it around grasping the wheel…” (*OT04*). Clinicians saw value in having the option of recommending older driver training for some seniors in their practice, but such a recommendation depended on the severity of an older driver’s medical concern.

Time for a 'tune up:' Keeping driving skills and road safety knowledge up to date in later life

Participants agreed that driver training can be valuable in later life. Some older drivers admitted having knowledge gaps regarding current traffic laws. For example, Hubert (*age 72*) stated, "there's probably a lot of little wrinkles in the highway traffic act that older drivers should be aware of and I don't know what they are." Some older drivers also shared their openness to "know how [their] driving is rated with today's standards" (*Russell, age 82*). Participants referred to seeking out training as a "check flight," a "tune up" or a "confidence builder." An older driver shared his experience of voluntarily seeking out a formal evaluation of his behind-the-wheel skills at a driving school: "I'd say, I got 67 out of a 100…I passed. [the driving instructor] said, "No you didn't." …sloppy in lines, sloppy with speeding signs or school signs… It's [for] my personal satisfaction that I was driving as well as I could be" (*Ned, age 90*).

While driving instructors described how some older drivers who came to see them were motivated to "make sure they're doing things the way they're supposed to" (*DI03, female*), such individuals were exceedingly rare. All stakeholders saw a need to promote the message that all drivers could benefit from ongoing training, not just older adults. A clinician surmised that a public health campaign could emphasize such a message: "it [the campaign] could be for everybody. Don't gear it at seniors because I think that's singling them out" (*OT02*).

Recommendations for the design and delivery of older driver training

'I'm a visual learner:' Tailoring training to older adults' learning styles and driving needs

Ensuring driver training is tailored to the needs of the older adult in question and that such training should consider differences in learning styles was raised across participants:

> I'm a visual learner. Some people are audio learners, I'm a visual learner and/or tactile, and if I'm doing something wrong, I need someone to drive with me and to say, "You're crowding the right-hand lane or you're crowding the left-hand lane." (*Eloise, age 71*)

During their interviews, driving instructors shared how their experience with training older men differed from that of older women: "…women tend to be more receptive [to feedback]; the men tend to be more stubborn and obstinate" (*DI04, male*), and that "women are more inclined to memorize what I asked them to memorize…more inclined to take my advice" (*DI02, male*). They also shared how older driver training should "relate…directly to them personally. You can't be saying, 'All drivers do this or all drivers do that.' You don't care; this is what you, as a senior driver, have to do" (*DI02, male*). Participants highlighted the importance of recognizing older adults' limited capacity to divide attention when behind-the-wheel. A driving instructor (*DI03, female*) confessed: "Every once in a while, I think I feel [an older adult] says "Oh yes, okay" just to make me stop talking." A clinician described the importance of recognizing the receptive capacity of older adults to process the learning:

> …looking at how we can empower people to identify when a change is needed in their lives and how do we then motivate them or help to motivate them when they're ready. So almost assess their ability for change and meet them where they're at. (*OT02*)

'I bought a new car:' Integrating contextual changes within older driver training

Older adults emphasized the need for driver training to be "fairly local," delivered in familiar community environments (e.g., seniors' centres), and available at a reasonable cost. Some indicated they would only participate if it was mandated by transportation authorities, as a condition of maintaining licensure. They were also more willing to participate in driver training if it would assist with navigating changes in local roadways (e.g., addition of roundabouts) or if they purchased a new vehicle with Advanced Driver Assistance Systems (ADAS). For example, Maria (*age 80*) shared: "I bought a new car and I think it might be useful to get [ADAS]… the dealer will give me an hour's training, but I might need more than that."

Driving instructors indicated a range of reasons why older drivers accessed their services, including: a family member's concern for their behind-the-wheel performance; spouses or widows needing to take on the role of 'primary driver' after their partner fell ill or passed away; relocation of their residence, which meant driving in new environments (e.g., highway driving, navigating underground parking garages); preparing for a government-mandated road test resulting from their involvement in an at-fault collision or a recent traffic citation; preparing for a road trip, and/or winter driving.

'Positive, and not punitive:' Formative feedback is important to older drivers

Older adults raised the notion of behind-the-wheel confidence as a potential barrier to their participation in driver training. For example, Adam (*age 84*) suggested, "I would think if you're concerned about your driving because you're losing your confidence and then someone gives you a 65 [e.g., of low score], I don't think you're going to be any more confident." Another older driver, Robert (*age 71*), suggested that once an older adult is a "tentative driver" regaining confidence can be a challenge. Driving instructors discussed how just being involved in an evaluation of one's driving abilities can impact performance: "[Most] have never had to do a test, so they're pretty nervous about this. We think that only teenagers are nervous about testing, but boy, seniors have a pretty healthy dose of test anxiety as well" (*DI04, male*).

Specifically, older drivers emphasized the need for training to affirm their behind-the-wheel skills, as Daniel (*age 79*) stated, "I would want them to tell me…[I'm] the greatest driver ever. Then my confidence would be sky high." An important consideration raised by service delivery providers was the need for feedback to be provided using "different learning modalities" (*OT02*) and to combine "tactical information…with actual practice…not just didactic" (*OT01*). Driving instructors described using multiple strategies in an effort to engage older drivers:

> Our first meeting is 2 hours and a lot of that is sitting together and talking, going over change of speed, direction, road markings, signage, maneuvers…then when they feel comfortable with me, and I feel safe with them, then we'll go out to the car and do an actual in-vehicle continuation. (*DI02, male*)

Driving instructors also explained that older drivers "are looking for assurance that what they're doing is correct" (*DI02, male*). A strengths-based approach was seen as key to ensuring the experience was "positive… and not punitive" (*OT03*).

Discussion

Understanding the impact of driver training aimed at the ‘well-elderly’ is a priority area for transportation research, especially given the established link between health and mobility in later life (Dickerson et al., 2017; Laliberte Rudman et al., 2006). A growing body of evidence suggests certain educational and training approaches are more effective than others when it comes to improving behind-the-wheel performance in the aging population (Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009; Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, 2007; Sangrar et al., 2019). Alongside this evidence, the perceptions of those involved in delivering and receiving such training should be considered to ensure these programs are meeting the needs of those being targeted. This study is the first to explore older adults’ perspectives concurrent with that of service delivery providers to identify factors that can influence participation in older driver training programs.

Findings suggest older drivers are more likely to seek out training after experiencing a major incident, such as a crash or a near-miss. Previous research has identified such incidents as critical opportunities to initiate a conversation about driving, including planning ahead for retirement from this activity (Hassan et al., 2015; Laliberte Rudman et al., 2006; Söllner & Florack, 2019). However, Taylor, Connolly, Brookland, and Samaranayaka (2018) cautioned that such conversations could also lead to premature withdrawal of licensure for those who are still medically fit-to-drive, thereby catalyzing the negative consequences linked to driving cessation in this age group. From their focus groups with older drivers [n = 27, *median age (min, max)* = 74 (74, 90)], Hassan and et al.

(2015) found the more aware older adults were of their health-related changes, the more likely they were to relinquish their driver's license. Conversely, our participants saw such changes as an opportunity to initiate a conversation about driver training.

In the current study, stakeholders saw friends and family members as critical conduits for encouraging participation in older driver training programs. However, a recent survey suggested that when older adults were simply told to take driving lessons by their family, such a comment did not influence their willingness to modify their driving (Caragata et al., 2019). To influence change in a senior's driving, participants in their study highlighted the importance of the individual making recommendations having been a passenger of the elder driver, be considered to be a good driver by the elder themselves, establishing a trusting relationship with good intentions, and providing concrete examples as rationale for their recommendations (Caragata et al., 2019). Unfortunately, in their survey of friends and family of older drivers, Söllner and Florack (2019) found that only 59% admitted that they would actually broach the topic of driving with their loved one if concerned. While the focus of this survey was on reporting medically at-risk older drivers, not driver training, study findings iterate the sensitivity in discussing this topic for both older drivers and their families. Caragata et al. (2019) also highlighted that older adults are most amenable to affirmation of their driving abilities and encouragement to continue driving. Stutts and Wilkins (2003) emphasized that in-vehicle assessment could prompt self-evaluation, and provide an opportunity for those who are still safe to operate a motor vehicle to refresh their knowledge and skills.

Previous research suggests training aimed at refreshing driving skills in later life should be tailored the needs of older drivers and include a ‘hands-on’ component (Korner-Bitensky et al., 2009; Kua, Korner-Bitensky, Desrosiers, et al., 2007; Sangrar et al., 2019). However, designing such programs is complex given the variability in how this training is described and delivered in the literature. For example, some programs consider ‘feedback’ to be informing an older driver of their on-road test score (see Stutts & Wilkins, 2003), while other programs engage them in verbal discussions, providing suggestions before, during, or after behind-the-wheel evaluation (Sawula et al., 2018). According to Musselwhite and Haddad (2010), a critical consideration for any training aimed at older drivers is to recognize the heterogeneity of this population in terms of their driving experience and corresponding capacity to change their driving habits. Older adults can vary in their driving-related knowledge and behaviours. As such, ensuring this driver training environment is conducive to their individual preferences and needs is critical (Keskinen, 2014).

The present study is the first to identify the importance of creating supportive environments for behind-the-wheel training in older adulthood. Feelings of anxiety, nervousness and general apprehension about the issue of driving were raised as a major concern among participants in the present study. For older adults, the notion of having their driving skills be evaluated, even for the purpose of training, heightens their feelings of nervousness and anxiety (Bhalla, Papandonatos, Stern, & Ott, 2007; Stutts & Wilkins, 2003). Bhalla et al., (2007) examined the experience of pre-test anxiety before an on-road evaluation in seniors diagnosed with Alzheimer’s Disease compared to those without any such diagnosis (i.e., the control group). Interestingly, feelings of anxiety were high in both groups prior to the test but were not found to impact on-road performance of older adults in the control group (Bhalla et al., 2007). As such, knowing one's driving skills are going to be judged and critiqued can raise negative emotions for all older adults, which can have further implications on their focus and confidence to respond to feedback when behind-the-wheel. Further research is needed to understand the impact of such emotions on actual driving performance during training, especially given older adults may be asked to focus on their deficits within this context.

Much research has focused on examining intervention effectiveness, with less attention directed at optimizing the design and delivery of driver training targeting an aging population (Sangrar et al., 2019). Of the few studies that have considered how best to raise issues specific to behind-the-wheel performance, acknowledging the vast experiences of drivers alongside self-perceptions of performance is crucial (Hassan et al., 2015; Hawley et al., 2017; Kua, Korner-Bitensky, & Desrosiers, 2007). Results from our study suggest feedback should be framed using a strengths-based approach to improve the behind-the-wheel behaviour of seniors. An example of such an approach is the Occupational Performance Coaching (OPC) model (Graham, Rodger, & Ziviani, 2013). In this model, 'information exchange' and 'emotional support' are emphasized where the 'coach' can employ various communication strategies to address knowledge gaps and encourage behaviour change, respectively (Graham et al., 2013). Service delivery providers interviewed in this study validated the need to build trusting relationships with older adults in order to raise the conversation about limitations in seniors' driving ability and areas for improvement.

Participants also highlighted the importance of ensuring behaviour change techniques are tailored to the older driver in question. Selected change methods should be based on best-practice evidence to ensure specific behaviours are targeted using effective approaches. Such an approach is described by the Intervention Mapping framework, which was used to guide the design of this study (see Bartholomew et al., 2016). This framework outlines an iterative approach to developing an intervention aimed at changing high-risk behaviours (e.g., critical errors behind-the-wheel), which includes ongoing stakeholder engagement. By incorporating multiple perspectives, the current study captures not only the preferences of older drivers, but also key pragmatic considerations for the design and delivery of programs that can encourage behaviour change.

Some gender differences were noted in participants' responses to coping with another driver's aggressive behaviours. Similar to findings by Gwyther and Holland (2014), women were likely to report avoidance behaviours, such as ignoring an aggressive driver, which may not be the best or safest strategy. In their study, younger women (i.e., age 25 – 64 years) admitted to using confrontational approaches in such situations, which may suggest a subtle shift in attitudes towards driving in this cohort. Gender differences were also noted in relation to willingness to adapt behind-the-wheel behaviours suggested by driving instructors. Older female drivers were viewed as more receptive to feedback than their male counterparts. Previous research suggested women are more likely to recognize changes in their driving, as they age (D'Ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Oxley, Charlton, & Fildes, 2005). Although the next generation of older drivers is expected to include a larger proportion of women, they continue to be underrepresented in research on driver training (Sangrar et al., 2019). Hence, the differential needs of men and women must be considered in the design of driver training programs aimed at the aging population.

Findings from the current study should be considered in light of certain limitations. First, older drivers were recruited from an existing database of individuals who had participated in driving-related research. Given their interest in volunteering for a study on training programs, our participants may not be representative of all older drivers, particularly those who may be reluctant to discuss their own behind-the-wheel skills. While our analysis reached saturation across all stakeholder groups with respect to emergent themes, only occupational therapists were sampled to provide a clinical perspective regarding the topic explored. Broadening the stakeholder groups to include perspectives of other service delivery providers (e.g., physicians, nurse practitioners), as well as friends and family, could enhance our understanding of factors that can impact participation in driver training at this life stage.

Strengths of the study include having an older driver assist with conducting the focus groups. We also analysed the perspectives of healthcare providers and driving instructors with regard to training whereas only older drivers have been included in similar research (see Laliberte Rudman et al., 2006). Additionally, participants were not provided with specifications of a training program, which may have allowed for more breadth in terms of considering key factors that might influence participation in older driver training. Future research should focus on identifying older adults who have the highest risk of collision that would benefit most from such training (Dickerson et al., 2017).

Conclusion

By exploring the perspectives of a diverse group of stakeholders, key factors that can influence older adults' participation in older driver training programs were identified. Older adults' awareness of their own behind-the-wheel skills is an important precursor for seeking out such programs. Encouragement from friends and family, tailoring training in accordance with their learning styles and feedback preferences, as well as consideration for how such the training context can be designed to facilitate uptake of knowledge and skills to improve driving in later life were highlighted. Incorporating these factors in the design of current and future driver training is critical to engaging older adults in programs aimed at optimizing their behind-the-wheel safety and mobility.

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Chapter Four: Refreshing Older Adults' Driving Skills (ROADSkills): A randomized controlled trial examining the effect of video feedback

Preface

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Title Page

Refreshing Older Adults' Driving Skills (ROADSkills): A randomized controlled trial examining the effect of video feedback

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Conflict of Interest
The authors declare that they have no competing interests related to the submitted work.

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Authors' Contributions
RS, BV, LG, LL and MP were responsible for study conception and planning. RS and BV were responsible for conducting the study. RS, LG and JM performed data analyses. RS drafted the manuscript with input from BV, and all authors provided input upon review.

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Highlights

- Tailored training has been shown to improve older drivers' on-road performance.
- Video feedback has the potential to remediate older adults' behind-the-wheel errors.
- Effects of feedback on self-report and objective driving performance were assessed.
- Drivers randomized to receive feedback significantly reduced the number of errors.
- Future work will examine the long-term impact of training on older driver safety.

Abstract

Background and Rationale:

This study evaluated the effectiveness of a customized video-based driver training program designed to improve the behind-the-wheel performance of community-dwelling older adults.

Method:

In this randomized controlled trial (RCT), 80 older drivers [*mean age* (SD) = 71.0 (3.9)] were randomly assigned to view one of two educational videos: 1) tailored video feedback on their driving (n = 40) or 2) a generic video on aging-in-place (n = 40). The primary outcome, total errors accrued in a 30-minute standardized on-road evaluation, was analyzed at baseline and 4 weeks after watching the assigned video. On-road evaluations were video-recorded and scored by a blinded rater. Self-reported scores on measures of driving behavior and abilities were also compared before and after the intervention.

Results:

At follow-up, the mean difference in the number of on-road performance errors [*mean* (95% CI) = -12.0 (-16.5, -7.6), $p < 0.001$] favored the intervention group with significant improvements in the domains of vehicle control, observing the roadway, and compliance with traffic rules. For the intervention group, within-group change on behind-the-wheel errors were significant [*mean* (95% CI) = -10.3 (-13.8, -6.8), $p < 0.001$], but not for the control group [*mean* (95% CI) = 1.7 (- 0.08, 4.2), $p > 0.05$]. There were no significant differences on self-reported measures.

Conclusion:

A novel, video-based approach that tailored feedback to older drivers reduced their behind-the-wheel errors 4-weeks post-intervention by a significant amount. Changes in self-reported driving behaviours and abilities were not significant. Future research will examine the long-term effects of such training on older drivers' actual and perceived abilities.

Keywords:

Older driver; driver training; aging; tailored feedback; on-road performance; randomized controlled trial

Introduction

Drivers aged 70+ are among those with the highest crash risks (Cheung and McCartt, 2011; Cicchino and McCartt, 2014) and are more likely to be injured or killed as a result (Regev et al., 2018). Some argue the crash risk of older drivers may be biased upward due, in part, to their propensity to drive shorter distances in high-traffic areas (Antin et al., 2017) where the likelihood of collision is greater (Langford et al., 2006). Others attributed their higher crash risk to decreased driving confidence and comfort (Coxon et al., 2015; Myers et al., 2008; Tuokko et al., 2016), poor driving habits (Cicchino and McCartt, 2015), and medical-related changes (Marshall et al., 2013; Marshall and Man-Son-Hing, 2011). Given the aging population, and the importance of driving to out-of-home participation in later life, determining the most effective ways to improve their driving is critical.

Many community-dwelling older adults are considered medically fit-to-drive, as they have yet to experience health and functional declines that preclude their ability to remain safe behind-the-wheel (Dickerson et al., 2017; Laliberte Rudman et al., 2006). Evidence suggests a combination of classroom-based driver education and behind-the-wheel training with a driving instructor can improve the on-road performance of this growing population of drivers (Korner-Bitensky et al., 2009; Kua et al., 2007; Sangrar et al., 2019). However, a closer examination of this evidence indicated considerable variation in how older driver training interventions were delivered across studies. For example, Bédard et al. (2008) provided only verbal feedback to older drivers following their respective behind-the-wheel evaluation whereas others supplemented such feedback with video-recordings that participants viewed in an effort to improve their behind-the-wheel skills (Anstey et al., 2018; Gagnon et al., 2019; Porter, 2013; Sawula et al., 2018).

Porter and Melnyk (2004) were one of the first to suggest the use of video recordings with older drivers. In a randomized-controlled trial (RCT), Porter (2013) found older drivers who received tailored video feedback significantly reduced their number of errors at follow-up ($p < 0.05$), while participants in control groups (in-class education only or no intervention) did not change. More recent studies also found error rates improved for older drivers who received video feedback when compared to those that only received in-class education (Anstey et al., 2018; Gagnon et al., 2019; Sawula et al., 2018). However, older driver training in these studies always combined video feedback with other interventions (e.g., classroom-based teaching, in-vehicle coaching). Hence, the independent effect of video feedback, as a training approach for older drivers, remains unclear for those who have not yet experienced medical or health-related changes that can impact their driving (Laliberte Rudman et al., 2006). These studies also did not report if and how gender might influence the effectiveness of this training, although their samples were stratified by gender (e.g., Anstey et al., 2018; Sawula et al., 2018). Research on older drivers has highlighted gender differences in relation to perceived driving ability (Jouk et al., 2016), driving patterns (Keay et al., 2018), and collision involvement (Islam and Mannering, 2006). Given these known differences, examining the effectiveness of older driver training on men and women is an important consideration. With a growing body of evidence demonstrating the benefits of video feedback on older drivers, the purpose of this study was to determine the effectiveness of a tailored video-based intervention on their actual and perceived on-road performance.

Methods

Trial Design

The Refreshing Older Adults' Driving Skills (ROADSkills) program was evaluated in a 2-arm, parallel-group, double-blinded (i.e., participants and assessment raters) RCT conducted between January and July 2019. For this RCT, all participant screening and assessment was completed by the primary investigator (RS) during the first of three visits (lasting approx. 2.5 hours each) to McMaster University, Hamilton (Canada). Outcome measures included a standardized on-road evaluation and self-report questionnaires. The primary outcome was total number of behind-the-wheel errors on the on-road evaluation. Once participants were enrolled in the study and completed baseline testing, they were stratified by gender and randomly assigned to either the intervention or control group. At their second visit, participants viewed one of two 30-minute video-recordings: feedback on their own driving (n = 40; intervention) or a generic video on aging-in-place (n = 40; control). Each participant was scheduled individually and watched their respective video on a large white screen in a classroom at the university.

After four weeks, participants were invited to return for a third session (lasting approx. 1.5 hours) where they completed a second on-road evaluation and repeated their self-report questionnaires. Each participant received an honorarium to cover fuel costs. This study was approved by the Hamilton integrated Research Ethics Board (HiREB: Study # 5387). Reporting of the study and intervention details were informed by the

Consolidated Standards of Reporting Trials (CONSORT) (Schulz et al., 2010) and the Template for Intervention Description and Replication (TIDIeR) (Hoffmann et al., 2014) (**Supplementary Files 1 & 2**).

Patient and Public Involvement (PPI)

This RCT was preceded by a systematic review of driver training programs aimed at the community-dwelling, healthy older adults (Sangrar et al., 2019), as well as a multi-stakeholder analysis exploring the motivations of older adults to participate in such training (Sangrar et al., *manuscript in prep.*). Three older driver advisors were consulted to ensure the feasibility and acceptability of the intervention protocol (1 female, 2 males; aged 70-80 years). The Guidance for Reporting Involvement of Patients and the Public (GRIPP-2) short form (Staniszewska et al., 2017) informed pilot testing of this protocol (**Supplementary File 3**).

Participants

Community-dwelling older drivers (*n* = 80) from Hamilton, Ontario (Canada), were recruited via advertisements in flyers, newsletters, and from presentations to community groups. If interested individuals knew another participant (e.g., friends, spouse) this information was recorded. Participants were eligible if they were at least 65 years old, but not older than 79 years, at the time of study completion. This age cut-off was to reduce co-intervention bias, as all drivers aged 80+ residing in the province of Ontario are mandated to undergo a group-based in-class education session as part of the Senior Driver Renewal Program (http://www.mto.gov.on.ca/english/driver/senior-driver-licence-renewal-program.shtml). Additional eligibility criteria included a valid driver's license and ownership and/or access to an insured vehicle, as well as the ability to speak English fluently. Criteria for exclusion included the diagnosis of a serious or terminal illness with medical contraindications for driving and not meeting the following criteria on cognitive measures: 1) score of < 21 on the Montreal Cognitive Assessment (Nasreddine et al., 2005; Rossetti et al., 2011) and; 2) ≥ 180 seconds or ≥ 3 errors on the Trail Making Test B (Bowie and Harvey, 2006; Reitan, 1958; Roy and Molnar, 2013). Prior to administering these measures, informed consent was obtained from participants to share scores on the cognitive screening with their primary care providers if they did not meet these criteria.

Outcome Measures

Standardized on-road evaluation (Primary Outcome)

All participants drove the same 12-kilometre route in their own vehicle, which took approximately 30 minutes to complete (**Supplemental File 4**). The standardized route was developed based on criteria from previous studies (Sawula et al., 2018) and in collaboration with a certified driving instructor, and incorporated maneuvers expected of drivers for licensure in Ontario (see https://www.ontario.ca/document/official-mto-drivers-handbook/level-two-road-test). Each drive was video-recorded using four GoPro Hero Silver 4 cameras mounted in the vehicle recording video in 1080p at 60-Hz (**Figure 1**). Additional driving-related information was also collected using an in-car recording device (PERSENTECH ©: speed, braking, acceleration, GPS location). This device has been previously used to monitor the on-road performance of older drivers (Koppel et al., 2017, 2016). The primary investigator (RS) accompanied participants during their baseline and follow-up drives and provided only verbal directions for route guidance. The investigator sat behind the front passenger seat, so as not to occlude camera views. Participants were asked not to converse with the investigator unless they required directional instructions to be repeated. They were also asked not to wear sunglasses if possible and to turn off the radio to optimize video/audio data quality. Testing was completed during daylight hours and outside of peak traffic times. Appointments were re-scheduled if there were hazardous weather conditions (e.g., ice, heavy snow and rain).

Each participant was scored on a range of pre-determined on-road maneuvers, as per previous older driver training studies (Gagnon et al., 2019; Porter, 2013; Sawula et al., 2018). These maneuvers included left and right turns, merging on and off a multi-lane highway, as well as driving in residential and business areas. These scoring criteria have demonstrated high test-retest reliability (ICC = 0.98) (Porter, 2013).

On-road driving maneuver errors were scored from the video-recordings by a single rater (a trained research assistant), who was blinded to group allocation, after baseline and follow-up drives were completed. Categories for scoring each maneuver included: 1) Vehicle controls (e.g., hand position, harsh acceleration or deceleration); 2) Procedural (e.g., vehicle position in the driving lane, responding to traffic signals); 3) Observations (e.g., mirror and blind spot checks, scanning intersections); and 4) Compliance errors (e.g., failing to yield to a pedestrian, speeding, or disobeying traffic signals). There were 32 maneuvers on this route. A driver could make a total 1009 errors, meaning higher scores are indicative of poorer performance.

As the scoring criteria were adapted to a new geographic location, intraclass correlation coefficients (ICC) were calculated for intra- and inter-rater reliability. Once all baseline and follow-up videos had been reviewed by the primary blinded rater, they were subsequently provided with 20 randomly selected videos to minimize the chance of recalling their previous ratings. Analyses demonstrated excellent intra-rater reliability [ICC (95% CI) = 0.95 (0.87, 0.98)]. A second blinded rater trained in the scoring protocol reviewed the same twenty videos, demonstrating good inter-rater reliability [ICC (95% CI) = 0.77 (0.50, 0.90)] (Koo and Li, 2016).

Self-report measures of driving behaviour and abilities (Secondary Outcomes)

Detailed descriptions of each self-report measure and their psychometric properties are available in **Supplemental File 5**.

Modified-Driving Habits Questionnaire (M-DHQ): The M-DHQ is a valid and reliable tool (Owsley et al., 1999; Song et al., 2015) that examines perceived driving abilities and driving habits, including domains of *current driving*, *driving exposure*, *driving dependency*, *driving difficulty*, self-reported *crashes* and *citations*, and *driving space*.

Driving Behaviour Questionnaire (DBQ): The DBQ (Cordazzo et al., 2014, 2016; Reason et al., 1990) measures perceived driving behaviours in terms of intentional violations and unintentional errors, such as failing to check mirrors or under/overestimating one's speed.

Perceived Driving Abilities – Current & Change (PDA – Current; PDA – Change): The PDA (MacDonald et al., 2008) measures older drivers' perceptions of their current driving ability within various driving scenarios, and perceived changes from 10 years ago.

Driving Comfort Scales – Day & Night (DCS – Day & DCS – Night): The DCS (Myers et al., 2008) measures older drivers' perceptions of their driving confidence and comfort. These self-report questionnaires categorize driving difficulty according to traffic and weather conditions as well as during the day and night.

Situational Driving Avoidance (SDA): The SDA (MacDonald et al., 2008) is used to assess older drivers' perceptions of how often they avoid challenging situations.

Situational Driving Frequency (SDF): The SDF (MacDonald et al., 2008) is used to assess older drivers' perspectives of how often they drive in challenging situations.

Intervention Group: Video feedback

Video-recordings of each baseline drive were viewed by a certified driving instructor. This instructor did not have access to any information about the drivers, including their group assignment, other than knowing they were participants in a study aimed at improving their behind-the-wheel behavior. The instructor was affiliated with a private driving school located in Ontario, Canada (Young Drivers of Canada ®). The instructor had over 25 years of experience in this role. The instructor was familiar with the standardized route, local traffic laws, and provided feedback to participants on their behind-the-wheel performance. For each situation, the instructor identified the specific maneuver and actions taken by the driver alongside an explanation of what impact the participant's performance during the maneuver might have on driving safety. Suggestions on how to improve performance were provided, as per previous studies (Porter and Melnyk, 2004; Sawula et al., 2018).

The instructor's s feedback was used to create individualized training videos for each participant in the intervention group. Each video was produced using Adobe Premiere Pro CC (v. 12.1, 2019). Each recording was 25-30 minutes in length and included an introduction to the driving instructor, explanation of the feedback format, and video clips of each situation with feedback. Each clip was repeated 3 times while voice-over feedback was provided by the driving instructor, along with a text-based summary (**Figure 2**). A written summary of their performance was provided to participants to take home after their feedback session.

Control Group: Generic video on aging-in-place

Participants in the control group watched a 30-minute video that described the benefits and challenges associated with aging-in-place, including community mobility (NPT Reports, 2015). Participants were also provided with written materials on this topic to take home (Government of Canada, 2015, 2012).

Sample size and statistical power

A sample size of 71 older adults was calculated based on data from similar studies that attained statistically significant results (Sawula et al., 2018). We considered minimal difference (MD) of within-group change on the on-road evaluation to be a conservative change of 20% in mean score following driver training, and a potential change of 5% in mean score in controls, based on previous findings (Sawula et al., 2018). We calculated that 30 participants were needed per arm to detect this between-group difference with a statistical power of 80% at the statistical significance level of $\alpha = .05$. Similar studies have reported a less than 4% attrition rate (Anstey et al., 2018; Sawula et al., 2018). We recruited 80 participants (40 per arm) based on a conservative attrition rate of 15%.

Random allocation, concealment and blinding

Participant allocation was stratified by gender (man, woman) using a permutated block scheme (groups of 4 by gender). Participants were randomized via equal allocation to treatment groups. The allocation sequence was determined using a computer-generated random number table by a colleague external to the research team who was blinded to participant identity. Only participants' identification numbers were provided for intervention assignment. For individuals known to each other (e.g., friends or spouses), the first partner to enroll was randomized in this way. The second partner was allocated to the same group to reduce the potential for treatment contamination. Group assignment was only released to the primary investigator who was the research coordinator and responsible for scheduling participants and intervention video development. However, the participants and the independent rater, who was responsible for scoring on-road evaluations, were blinded to group allocation.

At the outset of the study, participants were informed they would watch one of two educational videos related to transportation and that they would be offered the opportunity to watch the other video upon study completion. Every effort was made to explain the concept of blinding to participants and discourage them from discussing their assigned video intervention with friends and family while the study was active.

Video recordings of the on-road evaluation were scored by the independent rater blinded to participant identity, group allocation, and whether the drive was from the baseline or follow-up visit. Blinding was enforced by randomly assigning a unique number to each video after a participant had completed the entire study. Videos were forwarded to the rater in batches of 8-10.

Statistical Analyses

Baseline characteristics were described as means and standard deviations (SD) for normally distributed continuous variables and as medians and interquartile ranges (IQR) for variables with skewed distributions. Counts and percentages were used to describe categorical data. Paired sample t-tests were used to determine within-group differences between baseline and follow-up. Where assumptions for parametric tests were not met, non-parametric statistics (i.e., Wilcoxon sign-rank test) were used. A linear mixed effects regression model (with random intercept and random slope for participant) was used to analyze the treatment effect on the outcome variables. Fixed factors in the model were time, group, and the time by group interaction, where time 1 represented the baseline and time 2 represented the 4-week follow-up. Intention-to-treat analyses were conducted. Because the drop-out rate was 3.8%, it could be considered negligible (i.e., less than 5%) (Jakobsen et al., 2017; Schafer, 1999). Furthermore, as the reasons for loss to follow-up were unrelated to the missing values (e.g., travel), a complete case analysis was conducted in the primary analyses as suggested by Thabane et al. (2013).

Several sensitivity analyses were conducted to assess the robustness of the results. First, the effect of adjustment for baseline covariates (i.e., demographic characteristics) was explored by adding each variable as a fixed factor. Next, the analysis was conducted with imputation of missing primary outcome data using Predictive Mean Matching (He, 2010; StataCorp, 2013). Finally, the effect of including 8 pairs of participants who were known to one another was examined by excluding data from the partner who was enrolled second in each pair. Exploratory post-hoc analyses compared the intervention effect in 2 subgroups of interest defined *a priori* based on gender, and self-reported difficulty with driving on the Modified-DHQ. Regression diagnostics were conducted to examine whether residuals met assumptions of normality and homogeneity for all models. All tests for statistical significance were two-tailed, and the threshold α value was set at 0.05. All analyses were completed using STATA (v. 14.0; StataCorp LP, College Station, TX).

Results

Participant Characteristics

Of the 119 individuals screened between December 2018 and April 2019, eighty participants (*n* = 80) were enrolled in this study, randomized to intervention (*n* = 40) and control (*n* = 40) groups, and received their assigned interventions (**Figure 3**). Of participants who knew each other (couples or friends), there were 5 pairs in the intervention group and 3 in the control group. The mean age of participants at enrollment was 71.0 years (*SD* ± 3.9). Thirty-eight men participated in the study and 42 women (**Table 1**). The first three domains of the Modified-DHQ described participants' driving status, transportation patterns, and collision history. Participants in each group were similar at baseline. The most common types of on-road driving maneuver errors were scanning intersections (e.g., while driving or when stopped at a light), speed modulation while entering or exiting a multilane highway, checking blind spots when changing lanes, and hand positioning while driving (**Supplementary Materials 6**).

Primary analysis

Table 2 summarizes participants' mean scores on the on-road driving evaluation at baseline and follow-up, as well as change scores in total errors and for each sub-domain. **Figure 4** shows the mean change in the number of behind-the-wheel errors made at baseline and follow-up. At baseline, the mean number of errors made by all participants was 113.5 (*SD* ± 9.0; *min, max*: 85, 130) out of a possible 1009 errors. There were no between group differences in the total score or sub-domains at baseline. For participants in the intervention group who received video feedback, driving errors were significantly lower between baseline and follow-up [*difference in means* (95% CI): -10.3 (-13.8, -6.8), $p < 0.001$]. For control group participants, no significant difference in errors was found between baseline and follow-up. When comparing the change in driving errors between groups, intervention group participants made significantly fewer errors than control group participants [*difference in means* (95% CI): -12.0 (-16.5, -7.6), $p < 0.001$]. Similar between-group differences were found in the sub-domains of vehicle control errors, observation errors, and compliance errors, but not in the domain of procedural errors. Few participants were scored as having made procedural errors at baseline, compared to the other types of errors.

Secondary analyses

Summary scores and within- and between-group comparisons of self-reported measures are described in **Table 2**. Participants in each group were similar at baseline. Between-group differences in these measures were not observed.

Sensitivity Analyses

The primary analysis was replicated to adjust for gender as the stratification variable (i.e., as an independent fixed factor) and to adjust for other baseline covariates (i.e., additional fixed factors), both producing similar results (**Supplementary File 7**). Similar results were found when imputing missing data for the primary outcome. Excluding one of two participants known to each other also produced similar results.

Post-Hoc Exploratory Analyses

Exploratory analyses were conducted to examine the impact of different groups on the primary outcome (**Supplementary File 8**). For both genders, men [*difference in means* (95% CI): -9.7 (-15.2, -4.3), $p < 0.001$] and women [*difference in means* (95% CI): -14.2 (-20.7, -7.7), $p < 0.001$] who received video feedback significantly reduced their behind-the-wheel errors when compared with those in the control group of the same gender. Men in the control group made significantly more errors behind-the-wheel at the 4-week follow up [*difference in means* (95% CI): 2.8 (0.1, 5.6), $p = 0.04$]. While the difference between genders was not significant for those who received video feedback [*difference in means* (95% CI): -7.0 (-13.5, 0.3) $p = 0.06$], the effect on women [*difference in means* (95% CI): -13.5 (-18.6, -8.4), $p < 0.001$] was larger than it was in men [*difference in means* (95% CI): -6.7 (-11.3, -2.2), $p < 0.001$] (**Figure 5**).

Within each group, participants who reported driving difficulty on the M-DHQ at baseline were compared to those who did not. There were no significant differences in the reduction of driving errors within these sub-groups in either the intervention or control groups. Among those participants who did not report any difficulties with their driving, the on-road performance of those in the intervention group improved significantly compared to controls [*difference in means* (95% CI): -11 (-18, -5.7), $p < 0.001$]. The effect was similar in those that self-reported difficulties with driving at baseline [*difference in means* (95% CI): -12.1 (-17.8, -6.4), $p < 0.001$].

Discussion

Evidence suggests tailoring driver training to the needs of community-dwelling older adults is one of the most effective ways to improve their behind-the-wheel skills (Sangrar et al., 2019). Based on this evidence, video feedback has emerged as a potentially viable means to change seniors' driving behavior. However, studies have always combined this feedback with other training strategies, such as in-class education and/or in-vehicle instruction (Anstey et al., 2018; Gagnon et al., 2019; Porter, 2013; Sawula et al., 2018). Our study is the first to examine video feedback independent of other strategies to determine its effect on healthy older drivers.

Findings from our ROADSkills intervention suggest video feedback significantly reduced the number of errors made by older drivers 4-weeks post-intervention by at least 9.1%. While Sawula et al. (2018) found a 32.4% reduction in total number of errors, and more recently Gagnon et al. (2019) found a 17.3% reduction, older drivers in their respective studies also participated in group-based in-class education as well as on-road coaching with a driving instructor in addition to receiving video feedback on their behind-the-wheel performance. Our study demonstrated tailored video feedback alone can improve older adults' behind-the-wheel abilities in the absence of any other training approach. Participants improved significantly across multiple domains, including vehicle control, observation of the roadway, and their compliance with traffic safety rules. Although there was no significant change in the number of procedural errors, this result could be attributed to difficulties with scoring vehicle positioning by video. Sensitivity analyses suggested our findings were robust to potential differences in demographic characteristics, such as level of education or if a participant reported taking driver education prior to the current study (e.g., group-based classroom training).

Each driver in the intervention group watched a 30-minute video that used the same format with regard to the provision of feedback. Our multi-modal feedback approach included verbal, visual, and text-based elements where specific areas for improvement were highlighted by a driving instructor. The driving instructor followed an explicit protocol for providing feedback, as per previous studies (Sawula et al., 2018). Results from our study indicated certain behaviors, such as errors in scanning intersections or hand position on steering wheels, can be remediated at least in the short-term. There is potential for these changes to be sustained over the long-term. For example, in their study that examined the effect of video feedback on intersection scanning, Romoser (2013) found the effectiveness of their tailored training lasted up to 2 years post-intervention for their older drivers.

Receiving feedback on their driving can be a sensitive subject for many older adults, especially if they depend on driving to maintain their independence in their community (Caragata et al., 2019; Söllner and Florack, 2019). An older adult's identity has also been found to be closely linked to having a driver's license (Eisenhandler, 1990; Vrkljan and Polgar, 2007). As such, the transition from driving to driving retirement, which is known to have multiple adverse outcomes, might be eased by improving older adults' self-awareness of their behind-the-wheel abilities. Results of a recent qualitative study suggested the focus of older driver training should be "positive, not punitive" (Sangrar et al., *Manuscript in prep.*). In this training context, a strengths-based approach, where formative feedback on behind-the-wheel performance was provided, can improve uptake (Feng and Donmez, 2013). Older adults may be particularly motivated to improve their behind-the-wheel habits if it means extending their safe driving years (Sangrar et al., *Manuscript in prep*). Findings from the current study also suggested drivers who report no difficulties when driving align with previous research that suggested one's perceptions of their behind-the-wheel abilities do not always match their actual on-road performance (Chen et al., In Press; Riendeau et al., 2016). Our findings go one step further than previous research on older driver training, as those who reported no behind-the-wheel difficulties and those that did report issues both improved their driving with video feedback. This finding suggests older adults can benefit from such training, which addresses a major public safety need for programs aimed at improving the driving of our aging population as well as preparing them for driver retirement (MacDonald and Hébert, 2010).

The effectiveness of video feedback on reducing behind-the-wheel errors did not extend to self-reported measures of driving behavior and abilities. No changes were detected in the DCS-Day and DCS-Night within and between intervention groups at our 4-week follow-up. However, Anstey et al. (2018) found older drivers in their study who received tailored feedback self-reported higher rates of driving exposure 6 months after receiving their intervention. As such, future studies should consider tracking the long-term effect of video feedback on driving performance.

Exploratory analyses by driver gender suggested men and women benefitted differently from the intervention. There remains a dearth of evidence exploring the effects of gender on driver training, including video feedback. In their investigation of older drivers' perceptions of how their family members can influence their decision to stop driving, Caragata et al. (2019) highlighted older women are highly influenced by family members, particularly if they validate their ability to continue driving. Conversely, older men are more strongly influenced by family members when they urge them to stop or reduce driving (Caragata et al., 2019). Findings from our study suggest women may be more open to feedback and changing their behaviour accordingly. However, future research should examine gender-based receptiveness to feedback beyond family members. For example, driving instructors, whether providing feedback on an older driver's video or otherwise, could have a major influence on behind-the-wheel behavior, as demonstrated in the current study.

The ROADSkills program used a structured approach to convey feedback to older drivers. Such an approach aimed to prevent a driving instructors' individual teaching style from influencing uptake (Gagnon et al., 2019) and to create a standardized training format. This study is also the first to our knowledge to blind older drivers to their allocation to either the training intervention or control group. While all efforts were made to ensure blinding (e.g., randomizing known pairs to the same group; masking independent raters), there is the potential for breaches in this protocol. However, the researchers were not aware of any breaches that occurred. Participants who volunteered for the current study may also represent those who are more self-aware of their driving abilities, thereby underrepresenting those in this population who differ in their perceptions. The sample was also highly educated with most participants having post-secondary education compared to Canadian drivers of the same age group (see Gagnon et al., 2016). Finally, while this study demonstrated the ability for video feedback to change behavior, further research is required to determine the feasibility of delivering such an intervention in real-world settings, such as community programs or primary care where healthy aging initiatives are aimed at optimizing out-of-home mobility.

Conclusions

The current study examined the effectiveness of a video-based training intervention tailored to the needs of older drivers using examples from their own driving. This intervention significantly reduced the number of behind-the-wheel errors 4-weeks post-intervention. Although changes in self-reported driving behaviour were not found in the current study, plans are already underway to conduct a 6-month follow-up with participants, where long-term impact of such training on both perceived and actual behind-the-wheel behavior will be examined. Findings of this RCT add needed evidence on the effectiveness of tailored driver training using video-based methods that can improve the behind-the-wheel performance of older adults.

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Figures

Figure 1. Camera Angles

Figure 1. Camera angles recording on-road performance that were used for evaluation and feedback intervention

Figure 2. Example of text version of feedback provided for an on-road error

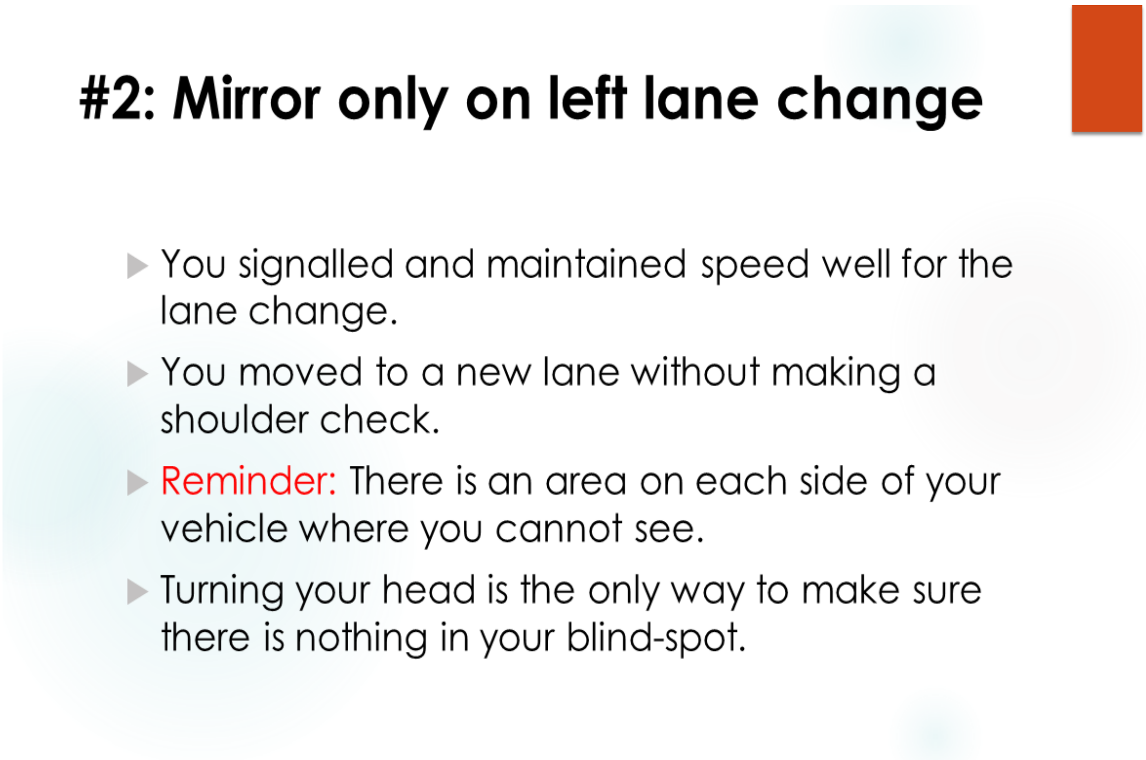


Figure 2 Example of text version of feedback provided for an on-road error

Figure 3. Consort Flow Diagram of participants through the study

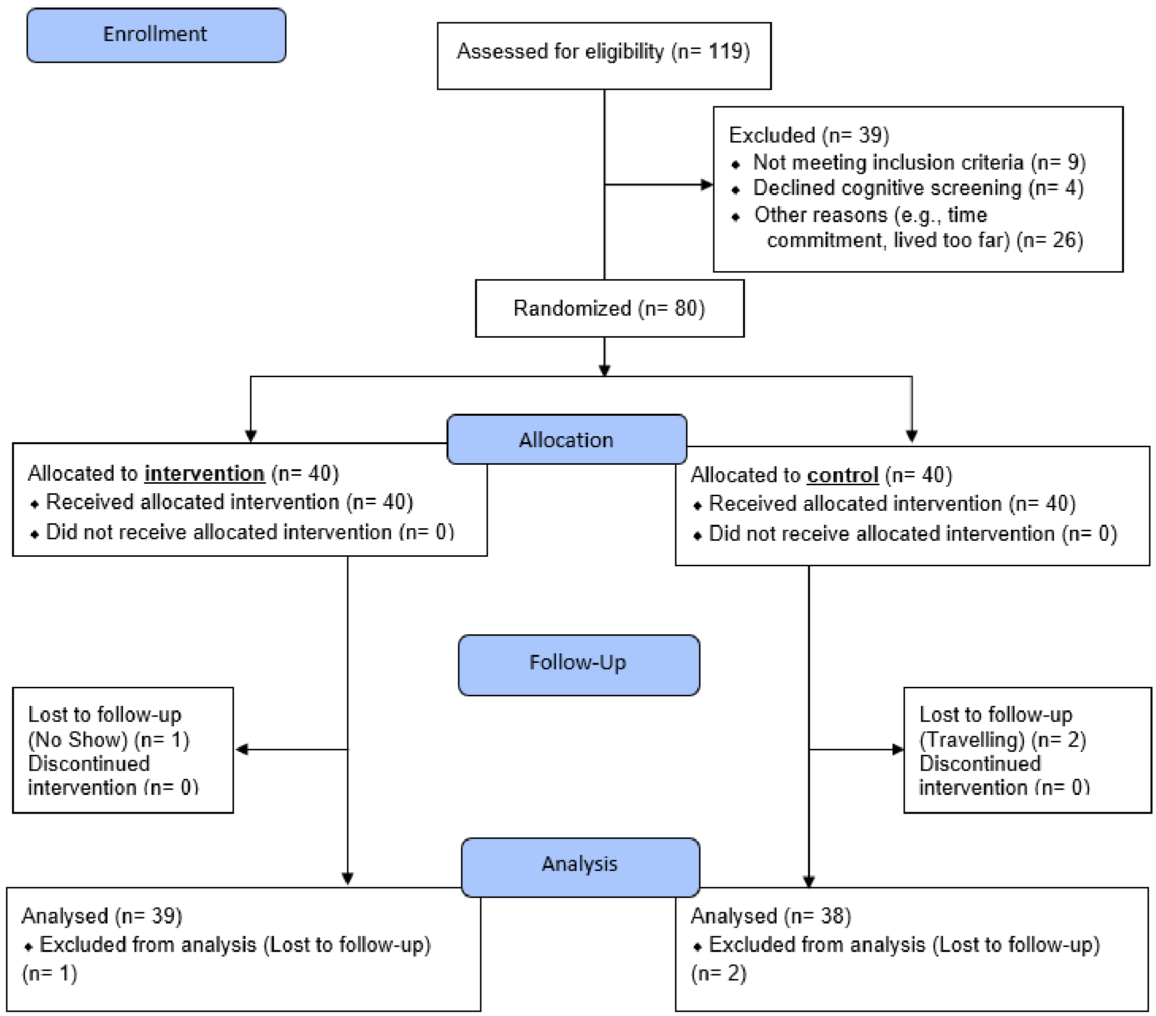


Figure 3 CONSORT Flow diagram of participants through the study

Figure 4. Change in behind-the-wheel errors

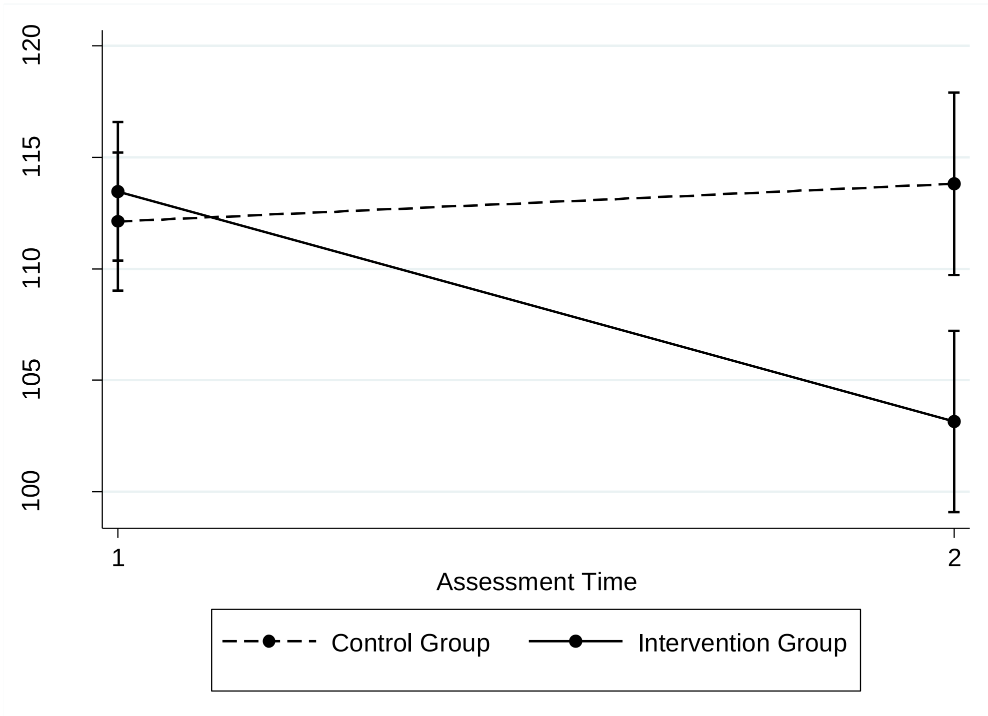


Figure 4 Line graph showing change in driving errors (predictive margins with 95% CIs) from baseline to follow-up for intervention group and control group participants.

Figure 5. Change in behind-the-wheel errors by group and gender

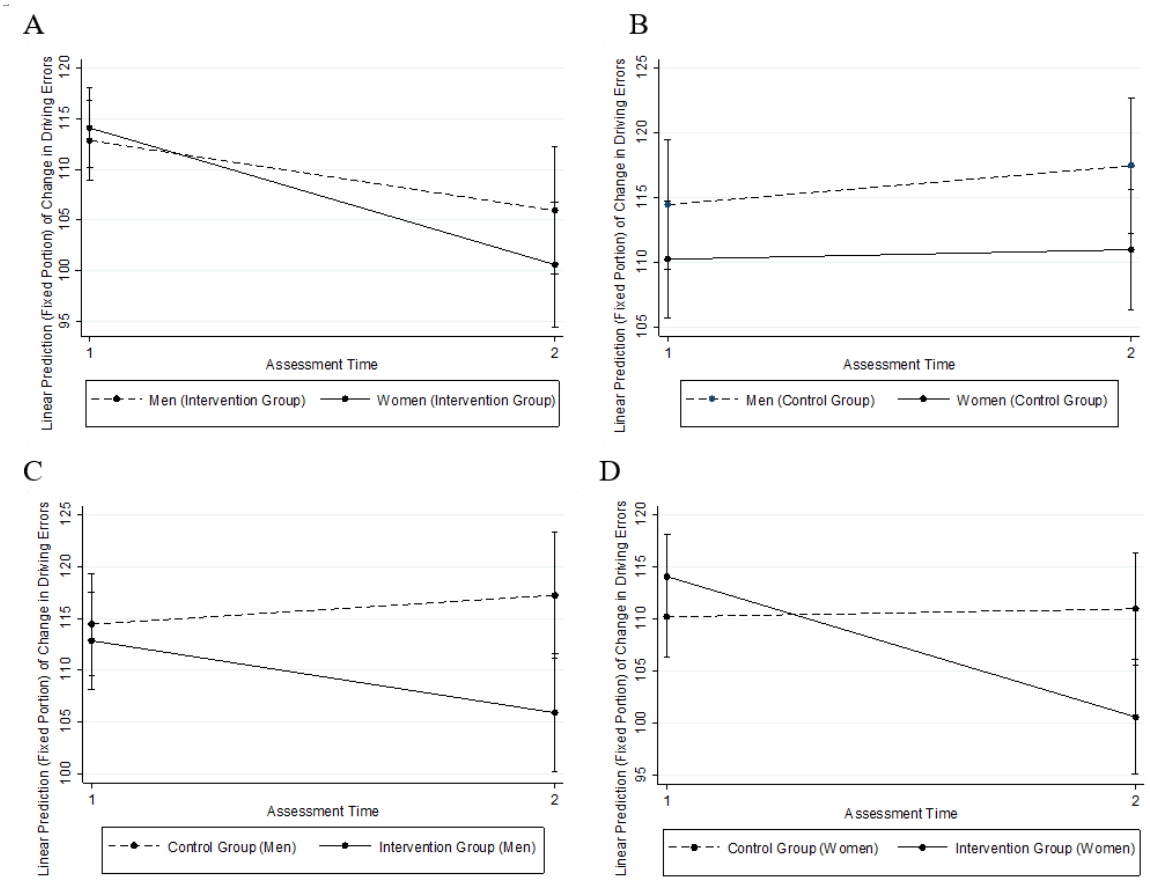


Figure 5 Line graphs showing the change in number of driving errors made at baseline and follow-up (predictive margins with 95% CIs) between (A) men and women in the intervention group, (B) men and women in the control group, (C) men in each treatment group, and (D) women in each treatment group.

Tables

Table 1. Description of study participants

Table 1. Description of Study Participants at Baseline			
	Total (n = 80)	**Intervention Group (n = 40)**	**Control Group (n = 40)**
General Characteristics			
Age (years) [*mean (SD)*]	71.0 (3.9)	71.8 (4.0)	70.2 (3.8)
Female [n (%)]	42 (53.0)	20 (50.0)	22 (55.0)
# Medical Conditions [n *(%)*]			
0	15 (18.8)	5 (12.5)	10 (25.0)
1-3	56 (70.0)	29 (72.5)	27 (67.5)
4+	9 (11.3)	6 (15.0)	3 (7.5)
# Vision Impairments [n *(%)*]			
0	4 (5.0)	2 (5.0)	2 (5.0)
1-2	72 (90.0)	35 (87.5)	37 (92.5)
3	4 (5.0)	3 (7.5)	1 (2.5)
# Falls in Past 6mos [n *(%)*]			
0	68 (85.0)	33 (82.5)	35 (87.5)
1	10 (12.5)	6 (15.0)	4 (10.0)
2+	2 (2.5)	1 (2.5)	1 (2.5)
Driving Experience (years) [*mean (SD)*]	53.6 (6.4)	54.8 (5.0)	52.4 (7.4)
Level of Education [n *(%)*]			
Highschool	9 (11.3)	4 (10.0)	5 (12.5)
Post-Secondary	57 (71.3)	26 (65.0)	31 (77.5)
Graduate Degree	14 (17.5)	10 (25.0)	4 (10.0)
Living Arrangement [n *(%)*]			
Alone	27 (33.8)	13 (32.5)	14 (35.0)
With another driver	51 (63.8)	27 (67.5)	24 (60.0)
With another non-driver	2 (2.5)	0 (0.0)	2 (5.0)
Geographical Location			
Rural [n (%)]	11 (13.8)	7 (17.5)	4 (10.0)

Table 1. Description of Study Participants at Baseline

	Total (n = 80)	**Intervention Group (n = 40)**	**Control Group (n = 40)**
Received novice driver education			
Yes [n (%)]	40 (50.0)	18 (45.0)	22 (55.0)
Received additional driver education			
Yes [n (%)]	26 (32.5)	16 (40.0)	10 (25.0)
Modified Driving Habits Questionnaire (DHQ)			
Wear glasses/ contacts when driving [n (*%*)]	57 (71.3)	32 (80)	25 (62.5)
Wear seatbelt when driving [n (*%*)]	80 (100)	40 (100)	40 (100)
Preferred mode of getting around [n (*%*)]			
Drive self	77 (96.3)	40 (100)	37 (92.5)
Have someone drive you	1 (1.3)	0 (0)	1 (2.5)
Use public transit	2 (2.5)	0 (0)	2 (5.0)
How fast you drive [n (*%*)][1]			
About the same as posted limit	69 (87.3)	34 (85.0)	35 (89.7)
Somewhat faster than posted limit	10 (12.7)	6 (15.0)	4 (10.3)
Recommended to stop driving [n (*%*)]	0 (0)	0 (0)	0 (0)
Quality of Driving [n (*%*)]			
Excellent	9 (11.3)	7 (17.5)	2 (5.0)
Good	54 (67.5)	25 (62.5)	29 (72.5)
Average	16 (20.0)	8 (20.0)	8 (20.0)
Fair	1 (1.3)	0 (0)	1 (2.5)
Alternative option [n (*%*)][2]			
Ask a friend or relative	45 (57.0)	21 (53.9)	24 (60.0)
Call taxi or take bus	19 (24.1)	7 (18.0)	12 (30.0)
Drive regardless of condition	9 (11.4)	7 (18.0)	2 (5.0)
Cancel/ Postpone outing	3 (3.8)	1 (2.6)	2 (5.0)
Other	3 (3.8)	3 (7.7)	0 (0)

Table 1. Description of Study Participants at Baseline

	Total (n = 80)	**Intervention Group (n = 40)**	**Control Group (n = 40)**
Driving Exposure and Driving Dependency			
Days driven per week [n *(%)*]			
1-4	15 (18.8)	4 (10.0)	11 (27.5)
5-7	65 (81.3)	36 (90.0)	29 (72.5)
Places visited per week [*median (1st & 3rd Quartiles)*]	6 (5, 10)	7 (5, 10)	6 (5, 9)
Average km driven one-way [*median (1st & 3rd Quartiles)*]	10 (7.3, 20)	12 (8, 20)	10 (5, 15)
Number of km driven per week [*median (1st & 3rd Quartiles)*]	140 (80, 250)	186 (96, 337.5)	114 (80, 190)
Number of people travel with [n (%)]			
0	2 (2.5)	1 (2.5)	1 (2.5)
1-5	58 (72.5)	30 (75.0)	28 (70.0)
6-20	20 (25.0)	9 (22.5)	11 (27.5)
Driving dependency [n *(%)*] [3]			
I drive	48 (61.5)	26 (65.0)	22 (57.9)
About half and half	27 (34.6)	12 (30.0)	15 (39.5)
People I travel with drive	3 (3.9)	2 (5.0)	1 (2.6)
Crashes and Citations			
Crashes in past year			
Yes [n (%)]	5 (6.3)	1 (2.5)	4 (10.0)
Citations in past year			
Yes [n (%)]	6 (7.5)	2 (5.0)	4 (10.0)

Legend:
* $p < .05$; ** $p < .01$; *** $p < .001$
[1] Control Group (n = 39)
[2] Intervention Group (n = 39)
[3] Control Group (n = 38)

Table 2. Primary analyses of objective and self-report measures of driving ability

Table 2. Complete case analysis of objective and self-report measures of driving ability 4-weeks post-intervention						
Variable by Group	**[*mean (SD)*] or [*median* (*1st and 3rd quartiles*)]**				**Baseline to Follow-Up [*mean (95% CI)*]**	
	(n)	**Baseline (n = 80)**	***(n)***	**Follow-Up (n = 77)**	**Within-Group difference (Change)**	**Between-Group difference (Change)**
On-Road Evaluation (Total score)						
Intervention	40	113.5 (9.0)	39	102.8 (14.3)	-10.3 (-13.8, -6.8) ***	-12.0 (-16.5, -7.6) ***
Control	40	112.1 (11.2)	38	114.4 (11.6)	1.7 (-0.8, 4.2)	
Vehicle Control Errors						
Intervention	40	24.5 (7.8)	39	19.9 (9.3)	-4.3 (-6.8, -2.0) ***	-4.8 (-8.0, -1.6) **
Control	40	24.1 (7.2)	38	24.8 (7.8)	0.4 (-1.6, 2.5)	
Procedural Errors						
Intervention	40	2.6 (1.5)	39	2 (1, 3)	-0.6 (-1.1, 0.01)	-0.7 (-1.5, 0.2)
Control	40	3.2 (1.7)	38	3 (1, 5)	0.1 (-0.5, 0.7)	
Observational Errors						
Intervention	40	82 (75, 86)	39	77 (71, 86)	-4.4 (-6.7, -2.1) ***	-5.5 (-8.3, -2.7) ***
Control	40	81 (74, 85)	38	82 (75, 86)	1.0 (-0.2, 2.3)	
Compliance Errors						
Intervention	40	5.2 (2.2)	39	4.1 (2.3)	-1.1 (-1.9, -0.3) **	-1.3 (-2.3, -0.2)*
Control	40	5.4 (2.0)	38	5.6 (2.0)	0.2 (-0.5, 0.8)	
Modified Driving Habits Questionnaire (DHQ)						
Driving Difficulty						
Intervention	40	93.8 (84.4, 100)	39	93.8 (84.4, 100)	-0.2 (-2.0, 1.6)	-1.5 (-4.4, 1.5)
Control	40	92.2 (81.3, 100)	38	96.9 (75.0, 100)	1.3 (-1.2, 3.7)	
Driving Space						
Intervention	40	4.7 (.9)	39	4.4 (.9)	-0.3 (-0.5, -0.04) *	-0.1 (-0.6, 0.4)
Control	40	4.5 (.9)	38	4.6 (1.0)	-0.2 (-0.6, 0.3)	

Table 2. Complete case analysis of objective and self-report measures of driving ability 4-weeks post-intervention						
Variable by Group	**[*mean (SD)*] or [*median* (*1st and 3rd quartiles*)]**				**Baseline to Follow-Up [*mean (95% CI)*]**	
	(n)	**Baseline (n = 80)**	***(n)***	**Follow-Up (n = 77)**	**Within-Group difference (Change)**	**Between-Group difference (Change)**
Driving Behaviour Questionnaire (DBQ)						
Intervention	40	32.7 (15.1)	39	36.2 (17.6)	3.3 (-0.1, 6.7)	0.9 (-3.5, 5.4)
Control	40	34.3 (14.8)	38	37.2 (15.0)	2.4 (-0.5, 5.2)	
Perceived Driving Abilities – Current (PDA-C)						
Intervention	40	35.2 (5.4)	39	34.7 (5.9)	-0.4 (-1.7, 0.9)	0.1 (-1.8, 1.9)
Control	40	33.9 (6.0)	38	33.0 (6.2)	-0.5 (-1.7, 0.8)	
Perceived Driving Abilities – Change over 10 Years (PDA-Ch)						
Intervention	40	34.9 (8.1)	39	33.6 (8.6)	-1.2 (-3.4, 1.0)	-1.8 (-4.7, 1.1)
Control	40	33.3 (7.5)	38	33.6 (8.5)	0.6 (-1.2, 2.5)	
Driving Comfort Scale – Day (DCS-D)						
Intervention	40	78.0 (13.8)	39	77.5 (13.2)	-0.2 (-2.5, 2.1)	-1.9 (-5.5, 1.6)
Control	39	76.4 (16.3)	38	76.9 (16.7)	1.7 (-1.0, 4.4)	
Driving Comfort Scale – Night (DCS-N)						
Intervention	40	70.5 (17.1)	39	71.7 (16.2)	1.6 (-1.4, 4.6)	-1.2 (-6.5, 4.1)
Control	39	68.5 (19.8)	38	71.1 (21.9)	2.8 (-1.5, 7.2)	
Situational Driving Avoidance (SDA)						
Intervention	40	4.0 (0, 10)	39	4.2 (3.0)	0.1 (-0.6, 0.7)	1.0 (0.1, 1.9) *
Control	40	5.0 (0, 10)	38	4.5 (0, 9)	-0.9 (-1.6, -.3) ***	
Situational Driving Frequency (SDF)						
Intervention	40	37.8 (7.2)	39	36.6 (6.7)	-0.9 (-2.4, 0.7)	-1.0 (-3.1, 1.0)
Control	40	37.2 (6.1)	38	37.4 (6.3)	0.2 (-1.1, 1.5)	
Legend: * p < .05; ** p < .01; *** p < .001						

Supplementary File 1

CONSORT Checklist			
Section/Topic	**Item No**	**Checklist item**	**Reported on page**
Title and abstract			
	1a	Identification as a randomised trial in the title	124 (Title Page)
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	126 (Abstract)
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	127
	2b	Specific objectives or hypotheses	129
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	129
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	130
	4b	Settings and locations where the data were collected	129
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	Supplementary File 5
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	131

	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	135
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Sequence generation	8a	Method used to generate the random allocation sequence	136
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	136
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	136
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	136
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	136-7
	11b	If relevant, description of the similarity of interventions	N/A
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	137
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	138
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Figure 3

	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 3
Recruitment	14a	Dates defining the periods of recruitment and follow-up	129
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Tables 2 & 3 Supplementary Files
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Tables, Supplementary Files
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	Supplementary Files
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	145
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	145-6

Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	141
Other information			
Registration	23	Registration number and name of trial registry	N/A
Protocol	24	Where the full trial protocol can be accessed, if available	N/A
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	124

Supplementary File 2

Summary of the ROADSkills trial intervention using TiDIER criteria	
TiDIER Criteria	**Description of ROADSkills trial intervention**
Brief name	
Name	ROADSkills (Refreshing Older Adults' Driving Skills): Video feedback on behind-the-wheel driving performance for older adults.
Why	
Rationale, theory, or goal of the elements essential to the intervention	Engaging fit-to-drive older adults in training programs increases their knowledge of road rules or the impact of age-related changes on driving, or reduces driving errors (Golisz 2014; Kaye, Lewis & Freeman, 2018; Korner-Bitensky et al., 2009; Kua et al., 2007; Unsworth & Baker, 2014). A key feature of some retraining interventions aimed at remediating behind-the-wheel skills is performance feedback. Performance feedback is traditionally provided to the driver by a trained instructor during on-road practice, such as with novice drivers. Feedback provided during a drive has demonstrated effectiveness in reducing on-road errors up to 2 months post-training (Bédard et al., 2008; Marottoli et al., 2007; Sawula et al., 2018). However, several factors may decrease the immediate acceptance and long-term effectiveness of such on-road and real-time feedback: drivers' limited attentional resources to process feedback; recall of driving events and feedback after the drive; and procedural and situational knowledge of safe driving habits (Feng & Donmez, 2013). Addressing these factors, video-based strategies have been used to provide drivers with concrete visual examples of their driving performance (Lavallière et al., 2012; Porter & Melnyk, 2004; Porter, 2013; Sawula et al., 2018). These strategies highlight performance errors, re-iterate ideal performance and provide drivers with suggestions on how these errors can be overcome (Porter & Melnyk, 2004). The approach to video feedback used in our study was informed by previous research (Sangrar et al., 2019), combined with the perspectives of key stakeholders, including older drivers (Sangrar et al., *manuscript in prep.*).
What	
Materials	Baseline video: This video captures participants' on-road performance while driving on a 12km standardized route. The video depicts 4 views of the participant (front and side view of the driver, and front and rear

	view of the road). Speed and location information is then superimposed, as is a time stamp for the duration of the video. Video editing took a total of 20 minutes per video, followed by a total of approximately 2 hours to render. 30-minute Feedback Video: A template for this video covers an introduction to the intervention and driving instructor, instructions on how to scan the 4 views of the video with two opportunities to practice (view of the driver), and individual feedback on individual situations. Each situation allows the participant to view the clip twice to identify what they did well or what they can improve. They then see the written feedback while hearing the driving instructor's feedback, and a third viewing of the clip in question. Videos can include between 10-18 situations, depending on the amount of feedback provided by the driving instructor to fill 30 minutes. Video editing for each intervention takes a total of 30 minutes per video, followed by 75 minutes to render. Text-Based Summary: 2-page document that compiles written feedback from each situation, specific to the individual participant. Equipment: 4x GoPro Cameras; Global Positioning System (GPS) device; Adobe Premiere Pro CC ©; Race Render 3 by HP Tuners ©; Intervention Delivery Protocol; Large white screen/ Speakers; Video Projector; secure data storage devices. All paperwork are available from the research team upon request.
Procedures	Participants were scheduled for a one-on-one session with a research assistant. Upon arriving at the specified location at the university, they were escorted to a classroom and set up to watch the video in front of a large white screen at the front of the class. The research assistant confirmed the audio levels were sufficient for the participant. They reminded the participant that they would be watching one of two randomly assigned educational videos and that they were not to discuss the video they had watched with anyone until study. There was no opportunity provided for the participants to take notes or replay video clips. Research assistants discouraged communication about the video after the viewing to maintain standardization in intervention delivery.
Who provided	
For each category of intervention provider, describe their	*Video Development:* A certified driving instructor with 25 years of experience working with seniors watched videos of participants and provided feedback on their driving performance. They received instructions to provide feedback in a 3-step format (see Sawula et al., 2018). The research coordinator, a licensed occupational therapist,

expertise, background and any specific training given	incorporated the feedback into a template format for the video. This coordinator was trained in basic video-production. *Video Delivery:* Research assistants, undergraduate and graduate students who were not involved in any other phase of the study, were responsible for scheduling participants and coordinating the video feedback session. Each research assistant was trained to follow the intervention delivery protocol.
How	
Describe the modes of delivery of the intervention	The intervention was delivered in a one-on-one format. Each participant met with a research assistant who set them up to watch the video where they received tailored feedback on their own driving performance.
Where	
Describe the type of location where the intervention occurred	Classroom in at a university with large white screen for video projection and audio-visual equipment.
When and how much	
Describe the number of times the intervention was delivered and over what period of time	Participants were scheduled for one session (scheduled for 1 hour) to view the video feedback intervention. They were only provided with one opportunity to watch the video. Participants were allowed to take home a written summery of the feedback to review as needed.
Tailoring	
If the intervention was planned to be personalised, titrated or adapted,	Each participant viewed a video tailored to their own driving that followed a templated format for providing feedback on their behind-the-wheel performance. This production was created using video recordings from participants' baseline on-road evaluation. A driving instructor first viewed the video from the baseline on-road evaluation and identified situations where they provided feedback (i.e., they indicated the time stamp when the situation

then describe what, why, when, and how.	occurred and the relevant feedback). The research Coordinator then clipped these segments and incorporated them into a template for the 30-minute video, as well as incorporating an audio recording of the instructor's feedback. Videos were created using Adobe Premiere Pro CC. This process ensured the feedback was tailored to the individual participants but followed a standardized format across participants. Video delivery was standardized across participants. Participants also received a summary of the feedback specific to their drive on a standardized form.
Modifications	
If the intervention was modified during the course of the study, describe the changes	Not applicable.
How well	
If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	To ensure intervention fidelity, all research assistants delivering the intervention followed an intervention delivery protocol which outlined the instructions for communicating with the participant (e.g., a reminder to not discuss the video with others) and video-set up. Adherence to the intervention was pre-defined as attending the session to watch the video. Intervention adherence is reported in the article.

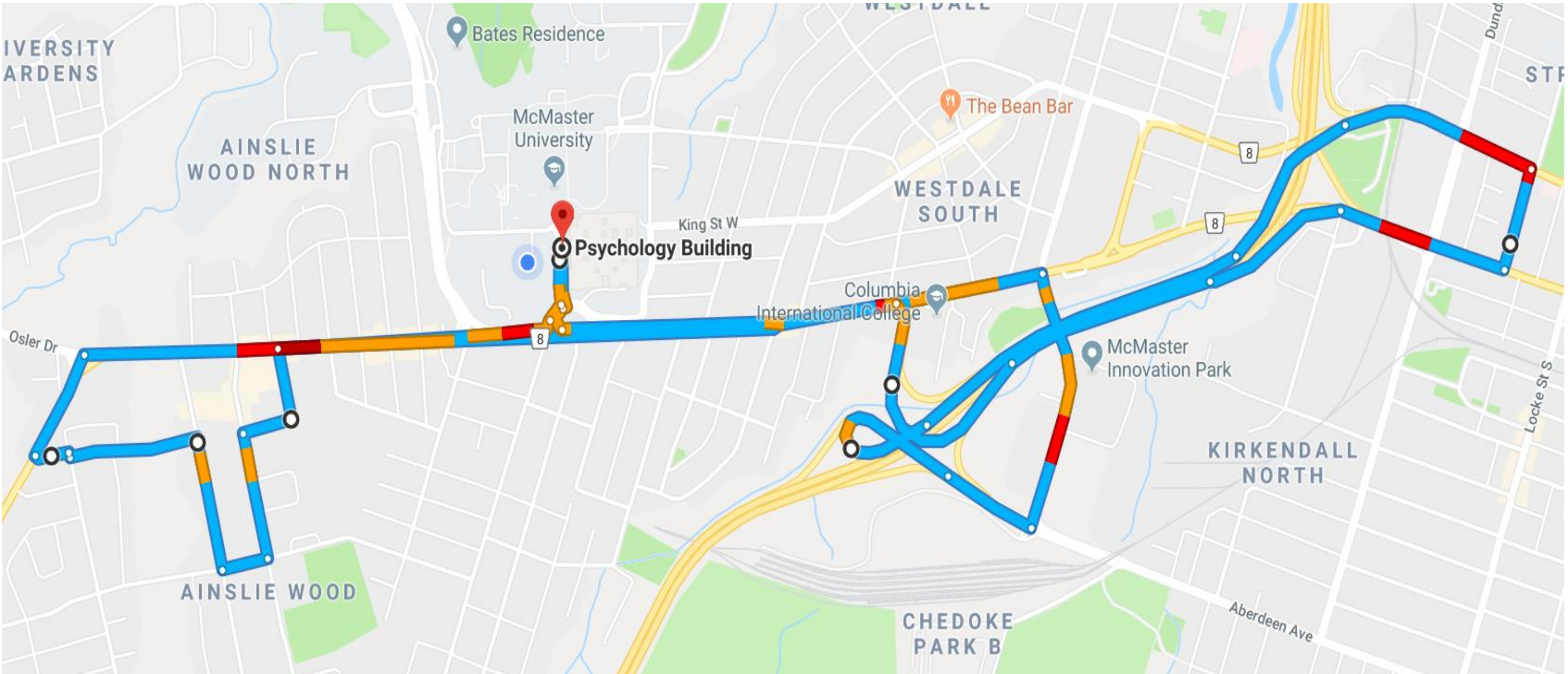
Supplementary File 3

Summary of Patient and Public Involvement (PPI) in the ROADSkills trial intervention using GRIPP2-SF criteria		
Section and topic	**Item**	**Reported on page**
1. Aim	Report the aim of PPI in the study [See Methods]	130
2. Methods	Provide a clear description of the methods used for PPI in the study [See Methods]	130
3. Study results	Outcomes – Report the results of PPI in the study, including both positive and negative outcomes Older driver advisors contributed to designing the trial and intervention protocols in terms of the participant experience. They suggested recruitment strategies, commented on venue accessibility (e.g., classroom at university), and provided feedback on the scripts used for obtaining consent and directions on the on-road evaluation. Their input informed the template structure of the intervention video (e.g., introducing the driving instructor and description of how to easily scan across the video clips), visual aesthetics and delivery protocol.	
4. Discussion and conclusions	Outcomes – Comment on the extent to which PPI influenced the study overall. Describe positive and negative effects The older driver advisors played an important role in this study given driving is a sensitive topic in older adulthood. Through their feedback, recruitment targets were surpassed, dropouts minimized, and the study was executed within the proposed timeline. However, reaching out to advisors individually required additional effort to explain study components and their opinions may not generalize to all study participants. These concerns, among others, should be considered when engaging stakeholders in research design (Boaz et al., 2018).	

5. Reflections/ Critical perspective	Comment critically on the study, reflecting on the things that went well and those that did not, so others can learn from this experience The ROADSkills' approach to engaging advisors was focused on using their perspectives to refine the intervention and study protocol. As such, advisors did not contribute to identifying the research question or selecting the methods, which may be beneficial for future investigations.	

Supplementary File 4

Map of baseline and follow-up on-road evaluation



Supplementary File 5

Description of self-report questionnaires

***Modified-Driving Habits Questionnaire* (M-DHQ):** The M-DHQ is a valid and reliable tool (Owsley et al., 1999) that examines perceived driving abilities and driving habits, including domains of *current driving*, *driving exposure, driving dependency, driving difficulty*, self-reported *crashes* and *citations*, and *driving space.* Individual domains have demonstrated good to high test-retest reliability ($ICC_{dependence}$ = 0.57; $ICC_{difficulty}$ = 0.87; $ICC_{crashes/citations}$ = 0.69; $ICC_{driving\ space}$ = 0.96) (Song et al., 2015). Outcomes are reported independently for each domain.

***Driving Behaviour Questionnaire* (DBQ):** The DBQ (Cordazzo et al., 2016, 2014; Reason et al., 1990) measures perceived driving behaviours in terms of intentional violations and unintentional errors, such as failing to check mirrors or under/overestimating one's speed. Responses are provided on a 6-point Likert scale ranging from 0 to 5, with higher scores indicating higher frequency. Multiple iterations of this tool have resulted in versions with differences in number of items and scoring scales (Parker et al., 1995; Reason et al., 1990). De Winter et al. (2015) found that items specific to driving violations correlated with speed behaviour at the time of a collision (r = 0.26), age (r = -0.46), and gender (correlation coefficient not reported).

***Perceived Driving Abilities – Current & Change* (PDA – Current; PDA – Change):** The 30-item PDA (MacDonald et al., 2008) measures perceptions of current driving ability within various driving scenarios, and perceived changes from 10 years ago. Total scores for the current and change sub-measures are calculated by summing responses to individual items. A higher score indicates higher perceived abilities. Between the two sub-scales the tool has demonstrated good internal consistency (α = 0.94, 0.87, for the PDA-current and PDA-change scales respectively), item reliability (α = .96, .90 respectively), and moderate test-retest reliability ($ICC_{2,1}$ = 0.65, 0.66, respectively) (MacDonald et al., 2008).

***Driving Comfort Scales – Day & Night* (DCS-D & DCS-N):** The 13-item DCS-D and 16-item DCS-N (Myers et al., 2008) measures an individual's own perceptions of their driving confidence and comfort. These self-administered questionnaires are comprised of categories of driving difficulty due to traffic and weather conditions during the day or night. Total scores for each questionnaire are calculated by averaging the scores for each sub-measure. Higher scores indicate higher levels of comfort and confidence. Both questionnaires were found to have high internal consistency and test-retest reliability (ICC = 0.70 for DCS-D, ICC = 0.88 for DCS-N). Scores on the DCS-D and DCS-N are significantly correlated (r = 0.79, p < 0.01). Males tend to score higher than females, with most drivers scoring higher on the DCS-D than on the DCS-N.

***Situational Driving Avoidance* (SDA):** This 20-item measure assesses drivers' perspectives of how often they avoid driving in various challenging situations. Higher scores indicate higher avoidance of driving in challenging situations. It has demonstrated high internal consistency ($\alpha = 0.87$) and test-retest reliability of ICC = 0.86 (MacDonald et al., 2008).

***Situational Driving Frequency* (SDF):** This 14-item measure assesses drivers' perspectives of how often they drive in various challenging situations. Higher scores (total scores vary from 0-56) indicate a higher frequency of driving in challenging situations. The SDF has high internal consistency ($\alpha = 0.92$) and a 7 to 14-day test-retest reliability of ICC = 0.89 (MacDonald et al., 2008).

Supplementary File 6

Types of formative feedback provided by the driving instructor across intervention group participants	
Type of Formative Feedback	**Number of occurrences compiled across participants**
Vehicle Control	**143 total occurrences**
Leaving the curb-side (not signalling)	20
Moving to the curb-side (not signalling)	23
Not signalling- Other (e.g., lane change)	3
Hand Position	24
Steering/ Shifting Gears (Manual Transmission)	5
Freeway Entrance (speed modulation)	31
Freeway Exit (speed modulation)	38
Procedural	**44 total occurrences**
Maintaining adequate space	14
Choice of driving lane	11
Wide Turn	15
Wandering	1
Lane Position	1
Appropriately responding to other drivers	1
Following a City Bus	1
Observation	**145 total occurrences**
General observation	2
Blindspot check before turn (e.g., to the right)	21
Blindspot check on lane change	27
Mirror check before braking	4
Mirror check after turning	11
Mirror check before and during a stop	21
Rear-view mirror checks during straight drive	2
Scanning intersections after a stop	23
Scanning intersections while driving	34
Compliance Errors	**69 total occurrences**
Speeding in a school zone	3
Speed (low)	4
Speed (high)	13
Stopping at stop signs/ red traffic lights	12
Stopping position	1
All way stops	2
Lane changes in an intersection	4
Wide left turn onto a one-way street	21
Amber light to red	8
Amber light (turning arrow)	1

Supplementary File 7

Sensitivity analyses - Linear mixed-effects modelling of the primary outcome measures (on-road evaluation)

Intervention effect on On-Road Evaluation			
Adjustments	Video Feedback (*n*)	Control (*n*)	Between Group Change (95% CI)
Primary model of on-road evaluation			
Model 1	39	38	-12.0 (-16.5, -7.6)
Sensitivity analysis #1 – addition of stratification variable (Gender)			
Model 2	39	38	-12.0 (-16.5, -7.6)
Sensitivity analysis #1 (intention-to-treat, no imputation) – addition of other covariates			
Model 3	39	38	-12.0 (-16.4, -7.5)
Sensitivity analysis #2 (intention-to-treat, multiple imputation)			
Model 4	40	40	-13.5 (-18.5, -8.5)
Sensitivity analysis (intention-to-treat, no imputation) – excluding 8 participants			
Model 5	34	36	-12.0 (-16.7 to -7.3)

Legend

* $p < .05$; ** $p < .01$; *** $p < .001$

Model 1: Linear mixed model adjusted for repeated measures accounting for clustering within treatment group and participant.

Model 2: Linear mixed model adjusted for repeated measures, stratification variable (Gender) and accounting for clustering within treatment group and participant.

Model 3: Linear mixed model adjusted for repeated measures, stratification variable (Gender), Baseline Characteristics (Covariates: Age, # of health conditions, # of vision impairments, # falls, geographical location, living arrangement, education level, novice training, additional training) and accounting for clustering within treatment group and participant.

Model 4: Linear mixed model adjusted for repeated measures and accounting for clustering within treatment group and participant with imputation for missing data (3 participants in follow-up).

Model 5: Linear mixed model adjusted for repeated measures, 8 participants (one from each couple) excluded, and accounting for clustering within treatment group.

Supplementary File 8

Post-Hoc Analyses on On-road Evaluation - Linear mixed-effects modelling of the primary outcome measures (on-road evaluation)			
	(*n*)	**Within Group Change [*mean (95% CI)*]**	**Between Group Change [*mean (95% CI)*]**
Differences in Gender			
***Intervention (Video Feedback)* (*n* = 40)**			
Men	20	-6.7 (-11.3, -2.2) **	-7.0 (-13.5, 0.3)
Women	20	-13.5 (-18.6, -8.4) ***	
***Control* (*n* = 40)**			
Men	18	2.8 (0.1, 5.6) *	-2.3 (-7.3, 2.8)
Women	22	0.8 (-3.2, 5.0)	
***All Women* (*n* = 42)**			
Intervention	20	-13.5 (-18.6, -8.4) ***	-14.2 (-20.7, -7.7) ***
Control	22	0.8 (-3.2, 5.0)	
***All Men* (*n* = 38)**			
Intervention	20	-6.7 (-11.3, -2.2) **	-9.7 (-15.2, -4.3) ***
Control	18	2.8 (0.1, 5.6) *	
Differences in Driving Difficulty[1]			
***Intervention (Video Feedback)* (*n* = 40)**			
No difficulty	29	-10.3 (-14.5, -6.2) ***	0.2 (-7.7, 8.0)
Reported Difficulty	11	-10.2 (-15.3, -5.0) ***	
***Control* (*n* = 40)**			
No difficulty	22	1.7 (-2.2, 5.5)	0.4 (-5.0, 5.5)
Reported Difficulty	18	1.9 (-1.3, 5.0)	
***All participants who reported No Difficulty Driving* (*n* = 51)**			
Intervention	29	-10.3 (-14.5, -6.2) ***	-11 (-18, -5.7) ***
Control	22	1.7 (-2.2, 5.5)	
***All participants who reported Driving Difficulty* (*n* = 29)**			
Intervention	11	-10.2 (-15.3, -5.0) ***	-12.1 (-17.8, -6.4) ***
Control	18	1.9 (-1.3, 5.0)	
Legend: * $p < .05$; ** $p < .01$; *** $p < .001$ [1] A score below 90 on the baseline *Driving Difficulty* subsection of the Modified-Driving Habits Questionnaire is interpreted as reported driving difficulty.			

Chapter Five: Thesis Discussion and Conclusion

THESIS DISCUSISON AND CONCLUSIONS

Driving a motor vehicle is an important means of accessing out-of-home occupations that can enable social engagement in later life (American Occupational Therapy Association, 2014). Driving is the preferred mode of transportation among those aged 65 years and older (Turcotte, 2012; Vrkljan et al., 2018). However, the onset of age-related health and medical conditions can negatively impact one's ability to safely operate a motor vehicle (Marshall & Man-Son-Hing, 2011). In fact, seniors have the highest risk of being killed or seriously injured when involved in an at-fault motor vehicle collision (MVC) (Cheung & McCartt, 2011; Palumbo, Pfeiffer, Metzger, & Curry, 2019; Tefft, 2017). Emerging research has shown older drivers can benefit from a 'tune-up' of their behind-the-wheel abilities (e.g., Sawula et al., 2018).

Training older adults to improve their behind-the-wheel abilities has the potential to extend their years of safe driving (Dickerson, Molnar, Bédard, Eby, Berg-Weger, et al., 2017). While there is a growing body of research on the effectiveness of older driver training, the last systematic review of such research was published over a decade ago (see Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009; Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, 2007). The review conducted by Korner-Bitensky and colleagues (2009) found complex, multi-component programs can improve older adults' on-road performance. However, the independent effect of components that constitute such programs on key safety-related outcomes, namely knowledge of road rules and regulations, self-perceived behind-the-wheel skills and behaviours, and objective measures of driving performance, were not reported. Understanding the effect of older driver training on these outcomes is important to identify the best intervention approaches targeting this population.

This dissertation examined the most up-to-date evidence on programs aimed at refreshing the driving skills and abilities of older adults, while also considering the perspectives of those who would be involved in such training (e.g., older drivers, clinicians, driving instructors). The ultimate **aim** was to develop and evaluate a novel older driver training program. Hence, this thesis used a mixed-methods approach that addressed the following **objectives**:

1. Identify the most effective **training approaches** for improving older adults' driving performance (Chapter 2).
2. Determine factors that can impact older adults' **engagement in driver training** from the perspective of older drivers, driving instructors, and clinicians (Chapter 3).
3. **Design an older driver training program** based on the best evidence and with input from key stakeholders, including seniors, driving instructors and clinicians (Chapter 4).
4. Evaluate the **effectiveness of this program** on both subjective and objective outcomes assessing the behind-the-wheel performance of older drivers (Chapter 4).

Findings from each study are summarized in the section that follows. Contributions of this research to the literature on older drivers, as well as potential implications for clinical practice and policy alongside areas for future research, are considered.

Overview of Findings

Chapter #2: Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance

The aim of this systematic review was to examine evidence from prospective comparative trials (i.e., randomized controlled trials [RCTs] and non-RCTs) that were focused on older driver training (Sangrar et al., 2019). In a previously published systematic review of similar evidence, Korner-Bitensky and colleagues (2009) discussed the effectiveness of multi-component programs where the benefits of in-vehicle coaching with older drivers were noted. Our findings extend this evidence by highlighting the importance of tailoring interventions to the older adult in question. Tailoring the intervention to each participant was a key strategy utilized in older driver training programs that were found to be most effective with regard to key outcomes, namely road safety knowledge, self-perceived driving skill and behaviours, as well as objective measures of on-road performance, such as behind-the-wheel evaluation.

Results from our review also highlighted the breadth of approaches used to train older drivers. In particular, we found these approaches varied in terms of the driving-related skill or ability that was targeted and the outcomes that were measured. For example, the effectiveness of cognitive training on speed-of-processing, memory, reasoning (Ross, Freed, Edwards, Phillips, & Ball, 2017) were examined in relation to self-reported driving outcomes, where receiving such training over many years was associated with maintaining behind-the-wheel exposure. Interventions also varied in their delivery. Some were delivered to groups of older adults (Bédard, Isherwood, Moore, Gibbons, & Lindstrom, 2004) whereas others provided individually-tailored feedback from a driving instructor (Sawula et al., 2018). Interventions that included in-vehicle training were always combined with in-class group-based education. While the evidence on the effectiveness of in-class education itself has not been associated with changing actual behaviour (Bédard et al., 2004), the independent effect of tailored feedback on behind-the-wheel performance has not yet been studied in older drivers. Moreover, it was difficult to discern how such feedback was delivered in the included studies (e.g., verbal, written, combination), and whether particular techniques might be more effective than others at improving driving behaviour. We also found that participants in these studies had not been blinded to their intervention allocation. However, studies that used objective measures of driving performance, such as on-road assessments, typically blinded evaluators. Studies also varied in terms of how participants were randomized and the ways in which missing data were addressed. Interestingly, studies classified as having a low risk of bias (see Chapter 2, Figures 2 & 3) were those that examined interventions where tailored feedback was provided (Anstey, Eramudugolla, Kiely, & Price, 2018; Coxon et al., 2017; Marottoli et al., 2007; Porter, 2013; Sawula et al., 2018).

This review identified the most effective approaches for improving older driver training outcomes (i.e., Objective #1 of this thesis). As an alternative to traditional in-vehicle coaching with a driving instructor, evidence concerning the use of video to provide feedback to older drivers on their behind-the-wheel performance was promising. As well, when designing such an intervention, it is also important to consider older adults' motivations for participating in this type training. These factors were examined in Chapter #3.

Chapter #3: Older adults' motivations for participating in a 'tune-up' of their driving skills: A multi-stakeholder analysis

The purpose of this descriptive qualitative study was to explore stakeholders' perspectives of factors that can impact older persons' participation in driver training, which addressed Objective #2 of this thesis. We conducted focus groups with older adults as well as one-on-one interviews with service delivery providers (i.e., driving instructors and occupational therapists). Older participants in our study all had a valid license and did not yet have medical conditions that precluded their ability to drive. Themes that emerged from this study extended our understanding of older drivers' motivations for participating in training programs and their preferences for how such programs are designed.

From our analyses, several factors were identified that can influence an older adult's decision to seek out driver training. These factors included, but are not limited to, their level of insight (or lack thereof) into their changing driving abilities, witnessing or being involved in a near-miss or a crash, as well as their level of openness to wanting to improve their behind-the-wheel skills. In terms of program design and delivery, participants raised the importance of considering older adults' unique learning styles. Changes in the contexts in which they drive was identified as another means of promoting their engagement in driver training (e.g., purchase of a new vehicle with advanced technologies, moving to a new neighborhood). Older drivers also wanted to use their own vehicle when doing such training. Participants indicated tailoring the intervention to the specific needs of the older driver in question was critical, which reinforced findings from our systematic review.

Older drivers, clinicians, and driving instructors in this study raised the importance of using a strengths-based approach to frame feedback on driving where the focus should be on what an older driver is doing well and areas for improvement. This feedback approach aligns with previous studies that suggest focusing on a drivers' strengths during training can improve uptake with corresponding benefits to road safety (Feng & Donmez, 2013). From the interviews, another key area of consideration noted by driving instructors were gender differences where they described how older women were more receptive to feedback and advice on their behind-the-wheel performance than men. Participants also discussed how older driver training programs could be an important segue to conversations about planning ahead for driving retirement. Findings from our qualitative analysis informed our next chapter, which describes the design and testing of an older driver training intervention.

Chapter #4: Refreshing Older Adults' Driving Skills (ROADSkills): A randomized controlled trial examining the effect of video feedback

The final study in this thesis involved the development and evaluation of a driver training program for healthy, community-dwelling older adults. The *Refreshing Older Adults' Driving Skills (ROADSkills)* program was informed by both the systematic review and our qualitative analysis. Results from our review identified video feedback as a promising approach for improving their behind-the-wheel performance alongside our qualitative study that informed the design and delivery of the ROADSkills intervention.

To test the effect of this intervention on older drivers' on-road performance, we conducted a two-arm parallel-group RCT where the study participants and outcome assessors were both blinded to group allocation. The primary aim of this RCT was to determine the effect of video feedback on the number of behind-the-wheel errors made by participants during a standardized on-road evaluation. Secondary outcomes included self-report measures of drivers' perceived behaviours and abilities.

Our findings suggest older drivers who receive video feedback significantly reduced the number of errors they made when behind-the-wheel. Those who underwent the intervention demonstrated significant improvements, as reflected in their error rates, in the following subdomains: vehicle control (e.g., steering-wheel hand position), observation (e.g., scanning intersections), and compliance with road laws and regulations (e.g., speeding). However, improvements were not seen in the procedural subdomain (e.g., staying within one's lane). Sensitivity analyses indicated these between-group differences were robust to the effect of covariates (e.g., demographic characteristics), missing data, and if participants were known to one another (e.g., married couple, friends). Exploratory post-hoc analyses identified gender as a key variable where women were found to benefit more from the intervention than men, although these changes were not significant. The training was also found to equally benefit drivers who reported some difficulty with driving as well as those that did not report such difficulties. Changes in secondary outcomes (i.e., self-reported driving behaviours and perceived abilities) were not found to be significantly different following the intervention.

The video-based approach examined in this study was designed to account for the sensitivity with which feedback should be delivered to older drivers (i.e., as identified in Chapters 2 and 3). Use of video to provide feedback might be preferred by older drivers over in-vehicle coaching given its potential to reduce the cognitive load associated with processing in-the-moment information from a driving instructor (Porter, 2013; Porter & Melnyk, 2004). Our RCT was the first to demonstrate the effectiveness of an older driver training intervention using video feedback administered to participants independent of other road safety interventions, such as in-class education or in-vehicle coaching. In this Chapter, Objective #3 (i.e., to design a driver training program informed by research and user perspectives) and Objective #4 (i.e., to evaluate the effect of this program on perceived and objective outcomes) were addressed. This training approach might also encourage older adults to engage in discussions about their community mobility, including planning ahead for their ability to access out-of-home activities when driving is no longer possible.

Contributions to the state of evidence on older drivers

Studies in this thesis build on previous research on training programs aimed at refreshing the driving skills of older adults. Our systematic review of evidence (Chapter 2) suggested tailoring an intervention to the unique needs of the older driver can have positive benefits with regard to changing their behind-the-wheel behaviour. In our qualitative study (Chapter 3), participants discussed older adults' motivations for driver training, including their insight into changing behind-the-wheel abilities and the need for improvement. These findings provided the impetus for further development and testing of the ROADSkills program. Results from the RCT demonstrated older persons who receive video feedback that is tailored to their behind-the-wheel needs can improve their on-road performance. Taken together, the findings in this thesis extend our understanding of such training by emphasizing that **driver training programs should be relevant to older adults and meet their individual needs and preferences.** While the value of driver training aimed at improving driving skills in later life is well recognized in both research and policy (Dickerson, Molnar, Bédard, Eby, Classen, et al., 2017; MacDonald & Hébert, 2010), the ROADSkills intervention is the first to integrate older adults' needs and preferences, which may not only prevent collisions, but also present an opportunity to open a discussion about driving in later life. Such discussions are crucial given the adverse consequences loss of licensure can have on health and well-being in older adulthood (MacDonald & Hébert, 2010).

Ensuring interventions are relevant to the targeted population is one of the central tenets of both evidence-based occupational therapy and client-centred practice (Egan, Dubouloz, Von Zweck, & Vallerand, 1998; Hammell, 2001). In occupational therapy, intervention planning involves collaborating with clients and caregivers as well as integrating research evidence and clinical expertise (Bennett & Bennett, 2000). For example, let us consider a healthy, community-dwelling older driver who has been referred to an occupational therapist working in primary care. In this context, the clinician is responsible for ensuring the client understands the importance of examining one's driving skills in later life and the impact that age and health-related changes can have on behind-the-wheel abilities. With this shared understanding, together, the client and therapist can identify opportunities for improving behind-the-wheel skills, while incorporating the client's needs and preferences to determine the best intervention plan. This collaborative approach can encourage engagement in interventions and uptake of driving-related recommendations that result in actual behaviour change. From a clinical perspective, it is also important to consider *who might benefit the most from older driver training* (Dickerson et al., 2017) and *how the experience of participating in such training can be optimized in later life.* These considerations are further discussed in the section that follows.

Identifying older adults who might benefit most from driver training in later life

Research pertaining to older drivers has largely considered those aged 65 years and older as a homogenous group in terms of their demographic characteristics. However, there is mounting evidence to suggest differences in age-based cohorts and socioeconomic factors can impact driving-related outcomes within this population. In their systematic review of evidence on older drivers, Babulal and colleagues (2018) were the first to explore the impact of race and ethnicity on driving concluding there may be a link between driving status and health disparity in ethnic minorities that requires further exploration. Moreover, emerging evidence on 'low mileage bias' suggests older adults who drive fewer than 3000 miles annually have the highest crash risk. These drivers are also more likely to be female and aged 75 years and older (Antin et al., 2017; Hakamies-Blomqvist, Raitanen, & O'Neill, 2002; Langford, Methorst, & Hakamies-Blomqvist, 2006). Such drivers might find particular value from undergoing training with the intervention developed in this thesis. Unfortunately, participants in both the qualitative and RCT studies were not diverse in terms of race and ethnicity, hence, further validation is necessary. Findings from this thesis align with a growing body of evidence that suggests certain approaches to driver training might be better suited for some older adults than others (Classen, Wang, Crizzle, Winter, & Lanford, 2013; Coxon et al., 2018; Lane et al., 2014). For example, gender differences emerged as an important consideration when it comes to older driver training.

Sex and gender considerations for older driver training. In health research, it is important to ensure appropriate terminology is being used when referring to sex and gender. Gender is considered to be a socio-cultural factor whereas sex is regarded as a biological factor (Canadian Institute of Health Research, 2019). To date, the distinction between sex and gender has not always been clearly defined in traffic safety research. For example, recent evidence in this field suggests female occupants have a higher risk of fatality and injury due to their biophysiological structures (Carlsson et al., 2014; Islam & Mannering, 2006; Sato, Brolin, Svensson, & Linder, 2019). Gender differences have also been raised in the older driver literature in reference to their everyday driving patterns. Older men have higher rates of exposure and trip frequency when compared to women (Barrett, Gumber, & Douglas, 2018; D'Ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Dupuis, Weiss, & Wolfson, 2007; Gwyther & Holland, 2012; Keay et al., 2018). There is also evidence that suggests older women are more likely than men to report using self-regulating strategies, such as not driving on highways, at night, or during bad weather (Barrett et al., 2018; Keay et al., 2018). They are also more likely to report changes to their confidence when behind-the-wheel (Barrett et al., 2018; Hassan, King, &

Watt, 2015). Despite these differences, we found only one case-control study (see Nasvadi & Vavrik, 2007) that examined the impact of gender on driver training. In this study, men aged 75 years and older who attended a group-based in-class driver education program were more likely to be involved in a collision after participating in the program compared to controls. This form of driver training was found to have no effect on collision-involvement for men aged 55 – 74 years or women in either age category. Nasvadi and Vavrik (2007) attributed these findings to the notion that this group of drivers may not have been able to implement the knowledge they learned, suggesting that programs aimed at optimizing driving performance may be better suited to men in a younger cohort.

Driving instructors interviewed as part of our qualitative study (Chapter 3) also highlighted gender differences where they perceived older women to be more receptive to feedback on their behind-the-wheel performance than men. No gender differences were found in relation to the number of behind-the-wheel errors in either treatment group at baseline in the RCT. Following the ROADSkills program, both men and women who received video feedback demonstrated a statistically significant reduction in their behind-the-wheel errors. While the differences in number of errors between men and women who received training were not statistically significant, women made a greater reduction in these errors than men (see Supplementary Material 8, Chapter 4). Our study adds to existing evidence that suggests women are more likely to benefit from strategies aimed at improving their driving (D'Ambrosio et al., 2008; Gwyther & Holland, 2014). Overall, the study findings demonstrated video feedback is a viable strategy for both men and women aged 65 – 79.

Age, functional ability, and behind-the-wheel training. The ability to drive in older adulthood emerges from the confluence of many personal and contextual factors. As one grows older, the likelihood of experiencing age and health-related changes that can impact behind-the-wheel abilities increases. However, the effect of such changes can differ substantially within and between individuals. Older adults categorized as the young-old (65 – 74 years) often differ in their health and functional abilities compared to the old-old (75 – 84 years) and oldest-old (85+ years) (Lee, Oh, Park, Choi, & Wee, 2018; Moon & Emmanuel, 2018). For example, the young-old are less likely to have chronic medical conditions (Moon & Emmanuel, 2018) or other health problems that affect their physical mobility (Alonso et al., 2016). With age, there is evidence to suggest that trip distance and duration decreases but such changes can depend on the particular context of the senior (O'Hern & Oxley, 2015). Variations in travel patterns and other factors are captured by the Driving as an Everyday Competence (DEC) Model (Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010). This model conveys the complexity involved with how different factors can influence one's driving ability. In the DEC Model, self-awareness of one's behind-the-wheel skills is considered a moderator of driving performance. Results from our qualitative study also raised self-awareness of one's functional abilities as a trigger for seeking out training in later life. Consideration for how health and function can change (e.g., declines in physical mobility) is important when testing a training approach on an age-based sub-group of older adults. In our RCT, we targeted the youngest and healthiest cohort of older adults (i.e., ages 65 – 79 years). While the results from our evaluation indicate video feedback can improve driving in this cohort, intervention effectiveness needs to be examined among those from older age groups.

Optimizing the design and delivery of older driver training

Raising the topic of driving with an older adult can be a highly sensitive and emotional issue given many rely on driving as their main form of community mobility due to a lack of viable transportation alternatives. However, raising this topic is important due to the known consequences of loss of licensure on health and well-being at this life stage. Findings from our qualitative study (Chapter 3) highlighted how level of insight/self-awareness of older adults' behind-the-wheel abilities can influence their willingness to seek out and engage in older driver training. Given the importance of self-awareness, the question remains as to how programs can be designed and delivered to encourage older adults to participate in driver training. In this context, the Person-Environment-Occupation (PEO) Model (Law et al., 1996) may be helpful to examine the relationship between an older adult's perceptions of their skills and abilities, and their actual behind-the-wheel performance. The PEO Model describes occupational performance as the transaction between an individual's abilities, elements of the environment, and the demands required to perform the occupation in question (Law et al., 1996). For occupational therapists, behind-the-wheel performance can be viewed as a product of this transaction. Driver training delivered by an occupational therapist has been investigated in two recent systematic reviews where the importance of addressing clients' specific needs was emphasized (Golisz, 2014; Unsworth & Baker, 2014). Both reviews considered interventions aimed at individuals who have medical conditions that can impact their behind-the-wheel performance, which include off-road education. Most recently, Zanier and colleagues (2019) described a potential role for occupational therapists to provide off-road education to community dwelling, health older adults on vehicle maintenance and after-market technologies. Similarly, older adults interviewed in our focus groups also saw the value of engaging in driver training following the purchase of a new vehicle with advanced driving assistance systems (ADAS). These systems require drivers to adapt longstanding behind-the-wheel habits to new technologies as part of their everyday driving (Bellet, Paris, & Marin-Lamellet, 2018; Gish, Vrkljan, Grenier, & Van Miltenburg, 2017; Sangrar et al., 2018). Such adaptations could be facilitated through training programs tailored to address gaps in understanding of the purpose and function of ADAS. Similarly, driver training can also be designed to optimize the occupational performance of older drivers during periods of transition, such as when taking on the role of primary driver or moving to a new neighbourhood.

In our qualitative study, participants saw the opportunity for training to optimize older drivers' behind-the-wheel skills. This goal is closely aligned to those named and framed in the Goals for Driver Education in the Social Perspective (GDE5SOC) Framework (Keskinen, 2014),. The GDE5SOC Framework can be helpful for clinicians when considering an older client's goal with regard to driving and community mobility and then determine the appropriate training or other intervention that matches this goal. In the RCT, the focus was on improving the behind-the-wheel performance of older drivers.

Hence, the main goal of the ROADSkills program was to improve vehicle operation and mastery of traffic situations, which are considered the lower and more basic levels in the GDE5SOC Framework. However, by creating a program that targeted this need, we also provided a context in which other goals in the GDE5SOC can be raised. For example, an individual who received feedback on their driving may be more willing to engage in one-on-one education with a healthcare professional to plan for driving retirement. Findings from the systematic review indicate such education can improve self-regulation of one's driving in later life (see Owsley, McGwin Jr., Phillips, McNeal, & Stalvey, 2004; Owsley, Stalvey, & Phillips, 2003). This form of training would target the next level of the GDE5SOC Framework, which is focused on planning when and where to drive. Interventions aimed at a higher level of the GDE5SOC Framework (i.e., personal goals for life) might extend beyond driver training to include more general topics about healthy aging, as delivered in primary care settings (e.g., fall prevention, physical activity, nutrition). As such, the ROADSkills program provides a means with which healthcare professionals can open a conversation about driving, which sets the stage for maintaining community mobility in later life.

Driver training programs should also be designed in a way that optimizes learning in later life. Some studies included in our systematic review explicated the underlying theoretical approaches that guided their intervention design. Many designed their program using behaviour change theories. However, it is also important to consider educational frameworks that can facilitate knowledge transfer and information uptake in older adulthood. Tailoring interventions to the needs of aging drivers aligns with Tam's (2014) argument that older adult education should integrate and leverage the lived experiences of learners at this life stage. Recognizing this cohort of drivers as life-long learners, a tailoring approach to driver training was used as a means to integrate new knowledge with prior learning. The ROADSkills program was specifically designed to employ a multi-modal teaching strategy by building on previous studies that used video feedback in their training of older drivers (e.g., Porter, 2013). A tailored 30-minute video was developed for each participant which required an extensive amount of time for review of the baseline assessment and video production. The driving instructor who reviewed participants' videos was also trained on how to best deliver feedback for older adults, where strengths-based approaches are preferred (Bellebaum, Rustemeier, & Daum, 2012; Drueke et al., 2015; Van De Vijver, Ridderinkhof, & De Wit, 2015). However, the benefits of the tailored approach developed in this study must be considered in light of the personnel and resources required to develop the videos. There is much potential to streamline the ROADSkills program by further refining the behind-the-wheel assessment and corresponding video production process.

Advancing research on older driver training

Strengths, limitations and future considerations for older driver training research

Findings from this thesis set the stage for future research on older driver training and education. While findings from our qualitative study informed the design and delivery of the ROADSkills program, we do not know how older drivers perceived undergoing this intervention. As such, we are currently conducting follow-up interviews with older drivers who completed this program to understand their experience of the

ROADSkills program. Findings from these interviews will strengthen our understanding of older adults' perceptions of receiving feedback, as well as the timing of such interventions at this life stage. Gender differences, as previously noted, must also be examined knowing that older men and women can respond differently to feedback on their driving.

Results from our RCT (Chapter 4) demonstrated video feedback significantly reduced on-road errors. However, we did not find the same effect on self-reported outcomes. A reason we did not observe a change might be that the measures used were not designed to be responsive to change (e.g., to detect pre-post change in driving comfort following an intervention). Other reasons might be participants could have been over- or under-confident in their perceived abilities at baseline or might lack insight into their abilities. Consequently, participants might be more accurate on self-report at follow-up, having had an opportunity to reflect on their driving. Furthermore, it might take older adults longer than one month to perceive changes in their driving abilities and behaviours. Hence, we are engaging participants in a 6-month follow-up where the self-report questionnaires and on-road evaluation will be re-administered.

As previously noted, the same standardized route was used for pre-post assessment as well as for the training itself. Hence, a critical next step is to determine if the benefits of this training approach translate to the everyday environments in which older adult drive (i.e., evaluate their driving in familiar environments). An iteration of the ROADSkills program could also provide feedback on their driving in these familiar environments, making the intervention even more individualized. A future RCT could also compare our video feedback approach with in-vehicle training from a driving instructor, or if a combination of both video feedback and in-vehicle coaching can further improve their behind-the-wheel performance.

We also actively sought out and engaged older drivers as part of our research team (2 men and 1 woman between the ages of 70 and 80 years). These advisors shared valuable insights into the experience of driving in later life, as well as their perspectives of engaging older drivers in research focused on behind-the-wheel training. The older driver advisors were involved in co-leading our older driver focus groups (Chapter 3) as well as piloting our ROADSkills program and RCT protocol (Chapter 4). Going forward, further input from policymakers as well as those with expertise in business modelling could provide additional insight on the scalability and sustainability of this intervention within primary care settings or other contexts, such as seniors' centres, where there is a focus on healthy aging.

Potential implications for clinical practice and policy.

Healthcare professionals, particularly occupational therapists, can play an important role in enabling older adults to successfully age-in-place, especially when it comes to addressing their driving and community mobility (Canadian Association of Occupational Therapists [CAOT], 2019). Our interviews with occupational therapists who worked in primary care settings identified driving and community mobility of the aging population as a pressing issue that requires innovative approaches to address their complex needs. Dickerson and colleagues (2018) and others (Henderson et al., 2015) recommend initiating conversations about driving early and often in primary care that can help individuals understand how changes in their health can impact behind-the-wheel skills. The ROADSkills program could provide the context for such conversations where the focus would be on maintaining driving abilities while also developing a plan for community mobility when driving is no longer an option (CAOT, 2009; 2019). In fact, it has been reported that older adults may need to engage in driving-related programming more than once to better understand how their changing abilities can impact their everyday mobility (Betz, Scott, Jones, & DiGuiseppi, 2016; Hassan, King, & Watt, 2017). Given their expertise in both major transitions and facilitating performance and engagement in everyday activities in later life, occupational therapists are uniquely positioned to identify older drivers who might benefit most from this type of intervention. Currently, there are limited options available to clinicians when it comes to older driver training programs that are evidence-based. The program developed in this thesis sets the stage for providing such an option.

An opportunity exists to create integrated health and social programming that is focused on optimizing the community mobility of older adults (MacDonald & Hébert, 2010). For policymakers, findings from this thesis provide evidence that early intervention can improve behind-the-wheel behaviour of older drivers. In Canada, the province of Ontario is the only jurisdiction that mandates drivers aged 80 and older engage in group education to maintain their licensure. This approach has been shown to decrease crash rates in this population (Vanlaar, Hing, Robertson, Mayhew, & Carr, 2016). However, implementing behind-the-wheel education earlier could have even greater benefits for the aging population. Results from our RCT study demonstrated driver training, as early as age 65, can reduce the number of remediable errors. Implementing policies that encourage self-monitoring of one's behind-the-wheel abilities (Keskinen, 2014) could result in major public health savings by not only preventing road injuries and fatalities (Naumann, Dellinger, Zaloshnja, Lawrence, & Miller, 2010), but also helping individuals plan ahead for driving retirement as well as maintain their ability to age-in-place of choice.

Conclusions

This thesis explored how older adults' safe driving years might be extended by refreshing their driving skills. From our systematic review, we identified the most effective approaches for improving the on-road performance of older drivers. Consulting with key stakeholders led to insights on the design and delivery of training in later life. This evidence informed the design of ROADSkills, a novel training program targeting healthy community-dwelling older drivers. The effectiveness of this program was evaluated in an RCT, which showed that video feedback can significantly reduce behind-the-wheel errors in this population. Results from this thesis add to our understanding of how tailored interventions can improve driving in older adulthood. Our findings also highlighted the value of driver training when it is designed with the learning preferences of older adults in mind. Identifying who might benefit most from such training and pragmatic considerations for the delivery and dissemination of such programs will be the focus of future studies. Ongoing research aimed at enhancing the ROADSkills program should also consider gender differences. Collaboration with older drivers, as well as other key stakeholders, such as family members, primary care clinicians, and policy makers, is critical to ensure strategies are in put in place that support driving and community mobility in older adulthood.

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