COMPUTER-BASED COGNITIVE TRAINING PROGRAMS FOR OLDER DRIVERS: What Research Tells Us

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ABSTRACT

The aging driver population in Canada and the United States is a source of growing concern due to their involvement in road crashes. Research has shown that declines that come with aging can impair elderly drivers, making common driving maneuvers that they have performed for decades, such as turning left in an intersection, much more challenging. Of greatest concern, older drivers are at increased risk of cognitive impairment and dementia. Cognitive or "brain fitness" training programs have emerged in the last decade with the intention to improve safety among older drivers. These programs have been developed for on-line and computer use and are being marketed as products that are effective in improving cognitive abilities that decline with advancing age.

This paper critically reviews the literature to assess the extent to which the available scientific evidence demonstrates that computer-based cognitive training programs improve cognitive abilities and safety among older drivers. The available research suggests that such programs are likely effective to improve performance in relation to the specific basic cognitive tasks that are being trained (e.g., visual speed of processing). There is also evidence that these improvements generally fail to transfer to simulated and real-world driving tasks (e.g., hazard recognition while driving).

Computer-based cognitive training programs may not improve driving performance and produce safety benefits because they fail to focus on the right set of cognitive functions that are actually associated with specific driving tasks. Further research is needed to address this possibility. There is also emerging evidence that computer-based and simulated "driving-specific" training programs hold promise and are more likely to have transfer effects that improve older driver performance than those programs targeting basic underlying cognitive functions that fail to capture the complexities of driving and the important driving abilities that need to be mastered and maintained to drive safely. There is, however, a need to develop, and rigorously evaluate, new computer-based programs that adopt a more "practice-specific" approach in a realistic driving context to ensure that the learning transfers not only to the underlying cognitive abilities being trained, but also and more importantly, to better on-road driving, and ultimately to fewer collisions involving older drivers.

Disclosure

Dan Mayhew, senior author on this paper, chaired an Advisory Council of experts that provided guidance in the development of Lifelong Driver, an older driver computer-based cognitive training product of Adept Driver. Robyn Robertson and Ward Vanlaar, co-authors on this paper, were not involved on this Council or in Lifelong Driver development.

The mention of commercial training programs and companies that develop and/or market them was necessitated by the focus of this research and should not be construed as an endorsement of these products or companies in any way.

INTRODUCTION

The population in Canada, as in most Western cultures, is aging. This means that older persons will represent a larger proportion of the population in the coming decades. In fact, seniors are the fastest growing population group in Canada. According to population projections from Statistics Canada, it was estimated that there were five million Canadians older than age 65 (2012) in 2011, and the number of seniors will reach 10.4 million by 2036. Using today's licencing rates, it can be expected that more than 4.6 million Canadians aged 65 or older will hold a valid driver licence after 2021, rising to 6 million by 2031 (Robertson and Vanlaar 2008). The United States (U.S) is facing a similar population boost: by 2030, 70 million people in the U.S. will be older than 65 (twice as many as today), which translates into 25% of the driving population, corresponding to a 14% increase in this age group (Wilson 2007).

Older Driver Crashes

Healthy older drivers generally benefit from their accumulated experience behind the wheel which makes them more careful and safer drivers than their younger counterparts. However, despite a low crash risk overall, the aging driver population is a source of concern due to their involvement in road crashes. In Canada, in 2006, seniors aged 65 and older accounted for the second largest proportion of road deaths at 16% (462 road fatalities). The same group accounted for 15,545 (7.8%) of road injuries (Transport Canada 2007). Canadian seniors have the second highest motor vehicle death rate among licenced drivers, with an average of 15.7 deaths per 100,000 licenced drivers, compared to 9.6 deaths for drivers aged 45-54. In 2009, there were 494,756 Ontario licenced drivers aged 75 and older, 12,044 who had collisions that year. This translates to 243 collisions per 10,000 elderly licenced drivers (ORSAR 2009).

The crash type that is most common among elderly drivers is the angled collision. The rate of angled collisions increases significantly after age 70, although the rate of all other crash types, including rear-end and head-on crashes actually decreases for this age group (Romoser and Fisher 2009). These crashes most commonly occur at intersections, especially when elderly drivers are required to make a left turn (Bryer 2000; Mayhew et al. 2006). This may be because elderly drivers have difficulty assessing space to enter the traffic flow and experience failures in areas of perception and diagnosis. This means that when elderly drivers evaluate how much space they need to make a left turn across oncoming traffic, they are more likely to misjudge or miscalculate compared to drivers of other age groups, causing a crash. Situations with an increased amount of stimuli (e.g., several different lanes of traffic flowing in different directions, pedestrians, traffic signals) also cause difficulty for the elderly. In this respect, one study estimated that 19% of elderly driver crashes are due to their cognitive abilities being overwhelmed (Van Elslande and Fleury 2000).

Older Driver Impairments

For these reasons, as life expectancy is extended in our modern society, it is crucial to understand the ramifications of an aging driver population on road safety, and the physical, cognitive, and mental issues that these drivers may face. Notable declines that come with aging can impair elderly drivers, making common driving maneuvers that they have performed for decades, such as turning left in an intersection, much more challenging. To illustrate, sight diminishes with age. An elderly driver needs eight times more light to see properly as compared to a 20 year-old driver. This makes nighttime driving much more difficult (Lampman 2002). Similarly, loss of peripheral vision occurs with age, narrowing an elderly driver's field of view, and increasing their crash rate up to 30% (Voelker 1999). Older adults also have a diminished capacity for processing information, especially in their periphery due to sight loss, compared to younger drivers.

Other declines due to age effect short-term memory and speed of processing skills which are needed to efficiently survey the road and appropriately respond to hazards. For instance, age-related cognitive decline might lead to decreases in secondary looks (i.e., checking more than once for traffic or a free space for merging) and situational awareness (i.e., noticing pedestrians or other road users surrounding the driver), especially during turns (Romoser and Fisher 2009).

Impairments may also come from diseases or conditions that affect drivers in other domains, for instance, visual impairment such as cataracts, glaucoma, or macular degeneration (Lampman 2002). A study evaluating the impairments of elderly drivers injured in crashes found that those who had crashed were four times more likely to have glaucoma when compared to the control group which consisted of elderly drivers who had not crashed (McGwin et al. 1997).

Physical impairment may also result from conditions such as arthritis. Arthritis is when joints in the body begin to degenerate causing them to become red, swollen and painful. This pain and resulting loss of strength can cause drivers to become tired and distracted while driving. It also decreases the range of motion they have to properly survey the road (Lampman 2002).

In order to manage these medical issues, the elderly are often prescribed various medications; those with sedative effects can negatively affect their ability to drive. Older drivers generally take more medications than younger drivers and are more susceptible to the side effects of these medications on their central nervous systems (Ray 1992). Drugs such as antihistamines, antidepressants, benzodiazepines, and opioids are associated with increased crash risk and driving impairment such as drowsiness, loss of coordination, and dizziness (Wang and Carr 2004).

Of greatest concern, older drivers are at increased risk of late-life cognitive impairment and dementia (Carr and Ott 2010; Dobbs 2005). Driving impairment due to disease may be discreet in the beginning, being caused by conditions such as "mild cognitive impairment" in which individuals have greater memory problems compared to others of the same age, but whose memory problems do not significantly affect their functioning (Howe 2007). It is more difficult to detect drivers with such an affliction in the early stages, and it may be less crucial to do so.

Nevertheless, a significant number of those with mild cognitive impairment will develop dementia within five years (Gauthier et al. 2006). Dementia affects the brain and the ability to think, remember, and speak. It impairs a person's logical reasoning, memory, and their language skills. Anywhere from 3% to 19% of adults over the age of 65 have dementia. Unfortunately, cognitive impairment that is not due to a traumatic event (such as a stroke) is often only discovered by doctors in the later stages when it is more severe and therefore apparent.

Drivers with dementia are more likely to cause a crash due to carelessness or unsafe driving maneuvers such as improper turning or following too close (Cooper et al. 1993). It is not uncommon for drivers with dementia who have crashed to continue to drive, making this a significant cause of concern. Cooper et al. (1993) found that of 43 crash-involved drivers who had dementia, 36 continued to drive after their initial crash. Of those who continued to drive, 14 had at least one more crash before ceasing to drive. This means that drivers may still operate their vehicle for a fairly long time with impairment such as dementia (Cooper et al. 1993). This is concerning because their crash rate can increase on average 2-4 times compared to healthy drivers (Carr and Ott 2010).

In this respect, the number of drivers with dementia is on the rise: between 1997 and 2005, there were 210,000 people in Ontario diagnosed with dementia, 40,000 of which held active driver licences. More worrisome is that 9,000 of these drivers have been in car crashes, a third of whom had taken psychotropic drugs (Rapoport et al. 2008). It has been predicted by a Queen's University study that the number of drivers in Ontario with dementia will double by 2028 and reach 100,000.

Older Driver Programs and Practices

In light of the range of impairments that can affect senior drivers, and that are increasingly prevalent as drivers age, jurisdictions in North America are devoting increased attention to the older driver problem and looking to research to help develop viable and evidence-based solutions. In the past few years, several jurisdictions have undertaken reviews of older driver programs and policies (e.g., Florida, Maryland, Missouri, Ontario) in an effort to identify more strategic and evidence-based practices to improve road safety.

However, an international scan revealed that, while elderly driver programs and "fitness-to-drive" programs are available around the world and share a common ethos, there is great variance in the length of the program, the eligibility requirements for participants, and program components. Generally speaking, programs can be grouped into three categories:

- voluntary education courses and/or testing;
- medical assessment required if cause for concern is detected; and
- mandatory examination and/or mandatory medical assessment.

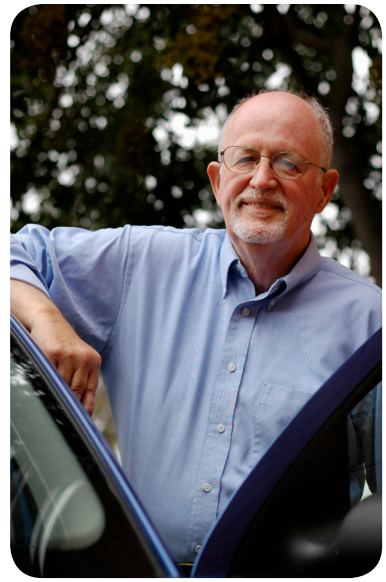
Yet there is surprisingly little consensus regarding the optimal ways to manage this population or structure the licensure process. For example, while some regions around the world are implementing mandatory age-based reviews of fitness-to-drive, other regions are dismantling such programs due to the lack of evidence of the effectiveness of such mandatory age-based reviews. Not surprisingly, few jurisdictions have education sessions which are mandatory for older drivers, while in other jurisdictions such sessions are strictly voluntary, and in others no such programs exist. There are also widespread differences in the cost of such programs (to both the jurisdiction itself and the driver), and the availability of alternative transportation options for seniors.

Web-based Programs for Older Drivers

At the same time, other non-government agencies and industries are also seeking solutions to help older drivers and their families increase senior driver safety on the road. It is well-established that cognitive abilities are critical for driving (Carr and Ott 2010; Lundberg et al. 1998; Staplin et al. 2012). Hence, such cognitive or "brain fitness" training programs have emerged in the last decade with the intention to improve safety among older drivers. These programs have been developed for on-line and computer use and are being marketed as products that are effective in improving cognitive abilities that decline with advancing age. As noted by Dunn and Hellier (2011), "these cognitive training programs attempt to either make older drivers more aware of the cognitive declines they are experiencing or slowing or reversing these declines" (p.3).

These programs are based upon the emerging science of "neuroplasticity" or "brain plasticity", which contends that the brain is changeable and that many aspects of the brain remain plastic even into adulthood (Fernandez and Goldberg 2009; Mark and Mark 1989; Pascual-Leone et al. 2011). Just as physical fitness improves by exercising the body, a logical extension is that brain fitness improves by exercising the brain. This is an especially compelling argument because of the emergence of the notion that the brain is "plastic" and is constantly changing throughout life. It follows for older adults that age-related cognitive declines could be halted or even reversed by exercising the brain.

By extension, it has also been proposed that brain training exercises have impacts on brain function that exist beyond the context of the training task (Edward et al. 2005; Shartz 2002; Wolinsky et al. 2006, 2009). This means that someone not only improves in the specific cognitive task being trained (e.g., speed of visual processing) but that there is a transfer effect to other untrained related, and even unrelated, cognitive tasks (e.g., identifying hazards when driving).



In light of the growing interest in and availability of these programs, it is important to recognize and understand the evidence that is currently available in relation to them. A review of this research is essential to inform our understanding of such products and their potential role in increasing the safety and driving performance of older drivers so that greater benefits can be achieved. Such is the purpose of this article. It critically reviews the literature to assess the extent to which the available scientific evidence demonstrates that computer-based cognitive training programs improve cognitive abilities and safety among older drivers.

METHOD

A web-based search identified three leading, commercially available computer-based cognitive training programs for older drivers:

- Drivesharp (produced by Posit Science);
- CogniFit Senior Driver (produced by CogniFit); and,
- Lifelong Driver (produced by Adept Driver).

It should be underscored that published research in the public domain regarding the training effects of these types of programs on older driver performance is fairly limited to date as determined by research cited on each of the three company's websites and key word web-based and literature searches.

Of the three commercial training programs listed above, Drivesharp is the most studied. The web-based and literature searches produced more than 10 journal articles and technical reports, several of which assess this program's training effects on driving-related measures, which was the primary inclusion criterion for accepting a report for review. Conversely, just one published study was found that examined the transfer effects of CogniFit Senior Driver training on the driving performance of older drivers, and a request to a senior contact at CogniFit did not result in any additional articles or reports. Lifelong Driver is a relatively recent program and has not been evaluated to date.

For this reason, it was most practical to place a main focus on the literature pertaining to Drivesharp, although the science related to the other programs is also considered. In order to place the research in context, a brief description of Drivesharp and some of the statements about its safety effectiveness by Posit Science are briefly described. Subsequently, the scientific evidence as it relates to its training effects on the driving performance of older drivers is examined. This article further reviews the limited research on the safety effects of the CogniFit Senior Driver training program and related literature on the transfer effects of cognitive training to older driver performance. It also addresses some future directions emerging from the review that can guide the development and evaluation of new computer-based cognitive training programs.

RESEARCH ON DRIVESHARP

About the Program

Drivesharp was developed by Posit Science, a brain-training software company. While initially called Insight, more recently the program has been marketed as Drivesharp by the American Automobile Association Foundation for Traffic Safety (AAAFTS) and the American Automobile Association (AAA), in partnership with Posit Science. According to Posit Science marketing materials produced in partnership with the AAAFTS, Drivesharp is built on a patented technology that was designed and tested by a global team of more than 50 scientists.

Drivesharp is a computer-based on-line software program designed to improve older driver's reaction time, and visual speed and attention. It consists of several interactive exercises called Road Tour, Jewel Diver, and Sweep Seeker.

Road Tour is an exercise to expand the useful field of view (UFOV) and improve the ability of older drivers to quickly notice a hazard in their peripheral vision, while focusing on the road in front of them. In Road Tour, the exercise involves correctly recalling a car displayed in the middle of a circle and also a particular road sign (that is one of many) near the edge of that same circle. These objects flash very quickly and are then hidden. The exercise becomes more difficult over time. According to Posit Science, "the placement and speed at which these images appear work to widen the field of vision and increase visual processing speed" (Posit Science 2010, p. 10-11).

Jewel Diver is an exercise in multiple object tracking designed to improve a user's ability to keep track of numerous moving objects at the same time, while ignoring ones that are not relevant. In this exercise, older drivers have to locate colored jewels that have been covered by identical opaque objects and surrounded by decoys, all of which move around. Over time, they have to find more jewels, and they move faster, for longer periods and over larger areas. According to Posit Science, "as the ability to follow the jewels improves so does the ability to keep track of multiple moving objects in real life, like pedestrians and other cars" (Posit Science 2010, p. 8-9; Posit Science Press release July 13, 2009).

Sweep Seeker is an exercise that uses collapsing tiles to speed up the brain's processing speed so older drivers can identify and react to objects more quickly (Posit Science 2010, p. 13-14).

Before beginning these exercises, users initially undergo an assessment to establish a baseline from which their progress is measured. After a few hours of work with the software, it is recommended that users complete another assessment to gauge progress. Exercises are sensitive to progress (i.e., they become more difficult when doing well versus easier when struggling). Posit Science recommends about eight to 10 hours of Drivesharp training to improve cognitive skills.

The Science Behind Drivesharp

The brain-fitness training exercises used in Drivesharp are based on the science of "brain plasticity", which, according to Posit Science, is the brain's natural ability to remodel itself throughout life. This theory contends that the brain is plastic throughout life and is constantly changing for better or for worse. Posit Science observes that their brain fitness training exercises influence that change in positive ways that can enhance overall performance and improve the quality of life. This is accomplished by taking a "roots-up approach" emphasizing "generalization," (http://www.positscience.com/brain-resources/what-is-brain-plasticity) or the extension of benefits beyond the trained task. This means that training in reaction time will improve performance on that specific task as well as produce generalized changes that improve driving performance overall.

According to the Drivesharp website (https://www.drivesharp.com/aaaf/science.html) and press releases, several studies have clinically proven that the program is effective. It further notes that, while results vary across individuals, on average persons who complete the Drivesharp program:

- cut their crash risk by up to 50%;
- increase their useful field of view (UFOV) by up to 200%;
- react faster to dangers; and,
- reduce stopping distance by up to 22 feet at 55 mph.

Research regarding the effectiveness of Drivesharp and evidence of improved skills from the training is explored in more detail in the following sections.

Useful Field of View (UFOV) and Cognitive Functions

The genesis of Drivesharp and Insight, an earlier version of this program, emerged from several decades of research into "useful field of view" (UFOV) by Dr. Karlene Ball and a research team (University of Alabama at Birmingham). UFOV was developed as a special test of visual speed and attention, and the evidence that is available suggests that training in UFOV improves the useful field of view (Ball et al. 1988; Roenker et al. 2009; Willis et al. 2006). In this regard, Posit Science reports that UFOV performance can be improved substantially by Drivesharp training.

Simons (2010b) in his review of the related literature cited by Posit Science found that this statement is likely accurate, but not surprising because Drivesharp incorporates the UFOV, so training with Drivesharp should improve performance on the UFOV. According to Simons (2010b), "practicing a task makes you better at a task even if it doesn't lead in improvements on other tasks". This observation is consistent with many studies that have shown that task-specific training results in improvements in that specific task but not in untrained and unrelated tasks (i.e., there are no transfer effects). To illustrate, Owen et al. (2010) conducted a six week on-line study in which 11,430 participants were randomly assigned to two training groups and a control group. During the six week training period:

- one group was trained on reasoning, planning and problem-solving tasks;
- the second group was trained on memory, attention, visuospatial processing and mathematical calculations; and,
- the control group was asked knowledge questions.

Pre- and post-training assessments showed improvement in the cognitive tasks that were trained but there was no evidence of transfer effects to untrained tasks, even when those tasks were cognitively closely-related.

However, much of the research that Posit Science cites in regard to Drivesharp relates to UFOV testing, and not whether training in UFOV actually improves UFOV performance, and by extension, improves an older driver's skills (e.g., the ability to identify hazards when driving). More recent research on Drivesharp has raised questions regarding what cognitive functions that UFOV targets actually improve with training (i.e., divided attention, selective attention and/or processing speed) and the extent to which there are transfer effects to more complex cognitive functions.

Sorenson (2012) assessed the effectiveness of Posit Science's Drivesharp in improving neuropsychological functioning in a normal aging sample. In this study, 32 older drivers aged 60-75 were randomly assigned to Drivesharp or a wait-list control group (i.e., began Drivesharp two weeks after the Drivesharp group did). This design allowed for assessment at three time points: the first at baseline; the second after the initial treatment; and the third, two weeks after treatment of the wait-list control. Participants were asked to engage in Drivesharp training 60 minutes per day, five days a week over two weeks, for a total of 10 hours which is the amount of training recommended by Posit Science. The neuropsychological tests included two measures to assess the areas of cognition that Drivesharp was designed to train (the Trail Making A, B, C, and D Tests and the Useful Field of View Sub-Tests) as well as one measure of cognition that is not directly trained by this program (the Raven's Progressive Matrices test which measures fluid intelligence). This latter test requires analytic and reasoning processes to understand visual analogies and solve multiple choice matrix problems. According to Sorenson, "fluid intelligence is a higher-level cognitive ability that allows us to solve novel problems" (e.g., problem-solving, learning, pattern recognition) (Sorenson 2012, p 4).

The results showed statistically significant improvement on Trail Making Test A/C (measures of visual scanning and processing speed) and the UFOV Selective Attention subtest. However, significant improvements were not found for Trail Making B/D (measures of visual attention, divided attention and executive control), the UFOV Divided Attention subtest, the UFOV Processing Speed subtest and the Raven's Progressive Matrices.

Overall, these results suggest that Drivesharp has a training effect on some but not all cognitive functions that are directly trained, and it did not have a transfer effect to a more complex cognitive ability (i.e., fluid intelligence) that was not directly trained by the program. In regard to the lack of transfer effects, Sorenson speculates that "there either was not enough training with Drivesharp to make the attentional improvements necessary to increase the broader function of fluid intelligence, or that the training program was not targeting the specific functions necessary for the transfer effect to occur" (Sorenson 2012, p. 50).

In summary, research suggests that UFOV performance does improve with Drivesharp training but this may extend to only some but not all of the cognitive functions that are being trained by UFOV exercises (i.e., improved visual scanning and processing speed but not visual attention, divided attention and executive control). Drivesharp training also does not appear to have transfer effects to other cognitive functions unrelated to UFOV. This is consistent with findings from the broader literature regarding the transfer effects of specific-trained cognitive tasks to untrained cognitive tasks.

Driving Reaction Time and Stopping Distance

Posit Science also reports that Drivesharp "training allows drivers to react faster providing an additional 22 feet of stopping distance at 55 mph". However this conclusion is "misleading" according to Simons (2010b). This is due to the fact that these findings are based upon a study by Roenker et al. (2003) using a computerized laboratory choice response time task, and not actual driving performance in reaction time and braking on-road.

In this study, Roenker et al. (2003) examined whether UFOV speed-of-processing training produced an improvement in driving on a simulator. Older drivers recruited into the study were assigned to one of three groups of older licensed drivers:

- 48 individuals exhibiting UFOV decline in the "high risk" speed-of-processing training group;
- 22 individuals exhibiting similar decline in a driving simulator training control group; and,
- 25 individuals who did not exhibit UFOV decline in a "low risk" reference group.

There was a two-week period, on average, between the pre- and post-training sessions. In addition, there was a follow-up assessment about 18 months after the post-training assessment.

Driving simulator measures included simple reaction time and choice reaction time. There were no group differences or training effects on the simple reaction time measure on the driving simulator. For the choice reaction time measure on the driving simulator, the speed-of-processing trained group showed improvements post-training, which was maintained at the 18-month follow-up. The choice reaction time test involved viewing a narrative film from the Doron film library at a distance of 5.8 meters. The stimuli were road signs (pedestrian, bicycle, right and left turn arrows) with and without a red slash through them. Participants reacted only to signs without a red slash, by braking for bicycle or pedestrian signs or by turning the steering wheel in the appropriate direction for right and left turn arrows.

In terms of the choice reaction time task, the improvements of the speed-of-processing trained group were evidenced in the driving simulator, not on road. Yet, as Simons observes, the study authors extrapolate these results to real-world driving. Roenker et al. state that "for a vehicle moving at 55 miles/hr, this improvement of 277m translates into a stopping distance 22 feet shorter" (p. 230). As noted by Simons (2010b), "the study did not show any effect of training on actual stopping distance and these speed improvements were not measured in a driving context – the claim was based entirely on faster performance in a laboratory choice response time task". In this regard, Simons notes that this claim is misleading for use in marketing the safety effectiveness of the Drivesharp training program. This criticism seems warranted given that the statement is based on one study with a small sample size of subjects using a driving simulator to measure driving performance, in this case choice reaction time, with no training effect evidenced for simple reaction time, which presumably would have also been expected to have been influenced by speed-of-processing training.

A further criticism of this study raised by Simons is that the subjects in the speed-of-processing group were impaired on UFOV performance and not those who performed normally on UFOV. This means that the training effects are limited on one measure (choice reaction time) in UFOV impaired older drivers and not to all older drivers. As a consequence, the training effects of speed-of-processing on all older drivers (i.e., the primary market for Drivesharp) and not just those impaired on UFOV, has not been established.

Dangerous Driving Maneuvers

Posit Science has also cited the Roenker et al. (2003) study, which included an on-road driving evaluation, as evidence that Drivesharp training reduces dangerous driving maneuvers by 36% (see also Delahunt 2010). Dangerous maneuvers were defined as ones in which either the driving instructor had to take control of the car or other vehicles had to alter their courses.

In this part of the study, older drivers in the two training groups (speed-of-processing trained group and simulated driving trained group) and the reference group completed a 14-mile urban/suburban route in about 50 to 60 minutes on three occasions (i.e., pre- and post-training and 18-months after training). Evaluators during these drives noted dangerous driving maneuvers as well as inappropriate driving behaviours (e.g., maintaining lane position, activating signals, stopping smoothly, searching, selecting gaps, turning, maintaining speed). In total, specific driving behaviours were aggregated into eight driving composites, which included dangerous behaviours, and a global driving rating.

The speed-of-processing trained group evidenced significant improvement on only one measure – fewer dangerous maneuvers. However, although the number of dangerous maneuvers for the speed-of-processing trained group as well as the simulator trained group dropped from pre- to post-test, they did not differ significantly from that of the low risk reference group. In fact, the difference between the three groups in the numbers of dangerous maneuvers was only significant at the 18-month follow-up period (i.e., the speed-of-processing trained group had significantly fewer dangerous maneuvers than the simulator-trained group and the reference group). The speed-of-processing trained group did not show significant improvement relative to the other groups in the seven other driving composite measures or in the global driving rating. By contrast, the simulator trained group improved on two on-road measures from pre-to post-training: turning into the proper lane and proper signal use.

Based on these results, Roenker et al. observed that speed-of-processing training improved on untrained tasks in terms of fewer dangerous maneuvers during the drive. Their reasoning is that these are driving behaviours that require rapid processing of complex visual information, which is targeted for improvement in speed-of-processing training. However, the positive findings on dangerous maneuvers were evidenced 18-months after training when only 28 of the 48 participants in this group at baseline returned for testing, making results rather tenuous, especially considering that dangerous maneuvers are rare events so few would have been recorded. And in this regard, Simons (2010b) observed that:

"Subjects averaged about 1 dangerous maneuver in about an hour of actual, on-road driving. The 36% improvement was based on a change from an average 1.01 dangerous maneuvers before training to an average of 0.65 in a test 18 months later (the average was 0.69 immediately after training). With such a low rate of dangerous maneuvers, it's possible that most drivers had no dangerous maneuvers at all and that a small subset had a large number of dangerous maneuvers. In other words, we don't know how many subjects had any dangerous maneuvers at all, and it's possible that most subjects had none at all either before or after training".

As well, the specific driving behaviours measured on road such as changing lanes and tracking also require "rapid processing of complex visual information" but the speed-of-processing trained group failed to demonstrate significant improvements in these behaviours or in the global rating, which incorporated all the driving behaviour scores.

In summary, the evidence cited that Drivesharp training reduces dangerous driving maneuvers is rather tenuous at best, and disregards the findings that other driving behaviours measured showed no significant improvement in the study.

Driving Performance

The study by Roenker et al. (2003) described in the previous section provides some, albeit relatively weak, evidence that speed-of-processing training improves choice reaction time on a driving simulator and dangerous maneuvers on road. However, this was an assessment of training in speed-of-processing, a component of UFOV, in contrast to the training effects of Drivesharp, which also includes training in selective and divided attention. Studies that have assessed the Drivesharp training program do not provide much, if any, scientific evidence that this program improves driving performance on a driving simulator, and more importantly, in real world driving (e.g., ability to identify potential hazards on the road). In fact, several recent studies, while finding training effects of Drivesharp on in-lab measures of useful field of view, do not find changes in actual driving performance.

Dobres et al. (2013) conducted a study to examine the effects of Drivesharp training on driving behaviour and visual behaviour. Participants included 32 older drivers aged 60-75 who were active, relatively healthy experienced drivers, with a valid driver's licence for at least the past three years and without crashes in the last year. Sixteen participants were assigned to the Drivesharp group and another 16 were assigned to the control group. Vehicle telemetry data, including mean driving speed, steering wheel position and wheel reversal rate, and acceleration events were obtained from an instrumented vehicle. Eye behaviour was captured with an eye tracking system (faceLAB 5.0). Older driver participants were also required to perform a secondary, clock visualization task, and a 1-back delayed digit recall task[1] during specific periods of highway driving in each session. In addition, older driver participants completed a battery of neuropsychological tests, which included the Attention Network Test (ANT), and UFOV test.

These tests were conducted at the start of each driving session prior to the driving tasks. The driving route consisted of about 10 minutes of urban driving to reach an interstate highway and about 45 minutes of highway driving. After the first driving session, the intervention group were given copies of the Drivesharp computer program and asked, over the following two weeks, to practice daily, with a recommended eight hours (480 minutes) of training. The control group was asked to return for a follow-up driving session two weeks after the initial one, without any training.

Results showed that the Drivesharp group averaged 500.8 minutes of training, with 10 of the 16 subjects completing at least 480 minutes of training, about the amount recommended by Posit Science. The authors found that Drivesharp training produced improvements in UFOV, at least in terms of the divided attention task but not processing speed, and selective attention. Drivesharp training did not significantly impact the other neuropsychological measures, including the ANT's reaction time and conflict subscales, or the measures assessed during driving in comparison to a control group. They concluded that "the overall pattern of results is nebulous and somewhat difficult to interpret" but consistent with previous studies: Drivesharp training leads to improvements on the UFOV test…" but "…the present data do not support the notion that Drivesharp engenders transferrable cognitive benefits…" (Dobres et al. 2013, p. 55).

The above study was part of an investigation on the ecology of cognitive training and aging conducted by Potter (2011) for a doctor of philosophy degree. In her doctoral dissertation, Potter observed that on-road drive results showed there were significant increases in scanning behaviour prior to the visual working memory task and more gaze dispersion increasing field of view. However, Potter also underscored that interpreting these results as Drivesharp training effects should be done with caution because of the possibility of practice effects and acclimation to the on-road drive.

More recent findings that Posit Science's Drivesharp training fails to improve driving performance emerged from a study conducted by Staplin et al. (2013). This study examined the effectiveness of four interventions designed to improve safe performance among healthy older drivers. Posit Science's Drivesharp program was one of the three interventions, which Staplin et al. described as a program to improve speed-of-processing and divided attention. The other interventions included:

- classroom driver education with supplemental behind the wheel instruction;
- clinical occupational therapy-based exercises to improve visual skills and attention; and,
- physical conditioning to improve strength, flexibility, and movement.

In this study, one hundred drivers aged 65 and older were randomly assigned to one of the four training interventions as well as to a control group that completed activities unrelated to driver performance or safe driving (e.g., subjects in the control group completed eight hours of activities with the research team principally consisting of a series of relaxation and meditation sessions or optionally a Cardio Pulmonary Resuscitation (CPR) certification class and/or nutrition counseling). Two types of measures were used: measures of effectiveness on tactical and strategic driving skills demonstrated through on-road assessments; and measures of performance on

1 As described by Dobres et al., "in the 1-back task, a sequence of 1-digit numbers is read aloud, and subjects are asked to repeat the digit that immediately preceded the one currently being spoken" (p. 52).

a driving simulator, including various attention and divided attention tasks. On-road and driving simulator measures were obtained before training, immediately following training, and three months post-training.

The three on-road drives (before, immediately after, and three months following the intervention) were conducted on different routes including the same roadway types (e.g., urban local roads, local roads, primary and secondary arterials, intersections). During each of these three drives, older subjects were assessed against 33 subscales within four domains of driving competency. The first three of these domains related to tactical skills and the fourth one to strategic driving skills. The four domains were:

- visual search and scanning tasks (e.g., scans environment, blind spot checks);
- vehicle positioning tasks (e.g., gap selection, following distance, lane changes);
- vehicle handling skills (e.g., appropriate speed, smooth steering, smooth acceleration, speed maintenance); and,
- cognitive and executive function tasks (e.g., divided attention, anticipates hazards, speed of processing).

The authors underscore that there were substantial missing data for the simulator assessments due to simulator sickness and related subject attrition (i.e, of the 92 older adults enrolled in the study who completed the first (pre-treatment) on-road evaluation, only 58 completed all three simulator appointments.

The Drivesharp program was modified for use in this study to allow for initially measuring baseline performance using a variation of the UFOV test. Research staff administered training to the participants in semi-private offices, separated by curtain dividers in an environment to minimize distraction. The training sessions were conducted in eight blocks of at least one hour each at least twice a week until all sessions were completed. Similarly, the study was designed so that participants in the other intervention groups and the control group received an equal level (eight hours) of contact with research staff.

The results showed that the Posit Science's Drivesharp group did not have significant gains relative to the controls in on-road or driving simulator measures, immediately following training and three months post-training. In regard to the on-road drives and specific tasks, for example, the Posit Science Drivesharp group actually showed a decline in divided attention (general) scores across the three drives; this group showed increases in anticipates hazards scores from the pre- and post-training drives but these performance improvements were not maintained three months later; and they showed no change in performance on speed-of-processing from the pre- and post-training drives. The Occupational Therapy Administered treatment group was the only one that showed significant training effects on the immediate post-treatment on-road assessment and on the delayed assessment.

In regard to the simulated drives and specific tasks, for example, all intervention groups showed performance gains relative to the control group on the most safety-critical measure, response time for peripheral hazard detection, but these differences did not achieve statistical significance. Staplin et al. (2013) observed that "there is no reliable evidence that any of the treatments was effective in reducing the response time to the different events in the driving simulator" (Staplin et al. 2013, p.86).

Finally, in terms of participant feedback, the Posit Science Drivesharp group failed to elicit responses significantly different from the control group during feedback sessions in terms of participant's agreement with the statements: "The training activity I participated in will help me be a safer driver, and I would recommend this training activity to a friend or family member". Based on this study, the Posit Science Drivesharp program failed to show evidence of transfer-of-training to driving and participants trained in Drivesharp, comparable to those in the control group, are less likely to express strong agreement with the safety benefits of this program for themselves or significant others.

An ongoing study at Virginia Tech Transportation Institute is currently examining the effectiveness of brain fitness training for senior drivers in limiting the risk of reduced field of vision associated with age. In this study, participants are being trained using Drivesharp or an in-vehicle training tool to expand UFOV, speed-of-processing and other visual functions. On-road driving performance of the two trained groups and a control group is being assessed pre-training, immediately after training, and at six-month and 12-month follow-ups. Results of this investigation are not currently available but will provide further scientific evidence on the extent to which Drivesharp training transfers to driving tasks and improves older driver performance.

In summary, several studies have examined the training effects of Drivesharp on older driver performance. These studies do not find improvements associated with Drivesharp training in measures of driving performance on a simulator and on-road. An ongoing investigation of the training effects of Drivesharp on driving performance on-road should shed some additional light on this issue.

Long-Term Training Effects

Posit Science has reported that Drivesharp has a long-term training effect that is still measurable five years after training (see Delahunt 2010). The research cited in support of this statement is unclear and/or does not appear to support this statement. Findings appear to stem from the ACTIVE trial, which was a large scale study of the effects of cognitive training on self-reported measures of daily performance years later, according to Simons (2010b). In this regard, the ACTIVE study has been described as the first large-scale, randomized trial to show that cognitive training improves cognitive function for up to five years later (Ball et al. 2010, p. 2,108). As observed by Simons (2010b), however, "the ACTIVE study did not directly measure driving performance and has produced relatively few documented benefits of cognitive training…". Moreover, the statement by Posit Science is particularly puzzling since the Drivesharp program was only launched in 2009. Hence, it is unclear how driving performance results from a group of individuals five years post-training were available.

Crash Risk

Posit Science has observed on the Drivesharp website that "drivers with poor UFOV performance are twice as likely to get into automobile accidents". There is ample research evidence from both retrospective and prospective studies that older drivers performing poorly on the UFOV test are involved in at-fault crashes more often than those who perform well on this test (Ball et al. 1993, 2002; Goode et al. 1998; Owsley et al. 1998; Owsley et al. 1991). Similarly, Simons (2010e) has described this observation as "accurate enough given that several studies consistently showed that people who perform poorly on the UFOV are poorer drivers".

However, these studies focused on the relationship between UFOV test results and crashes and not the extent to which training in UFOV, or in Drivesharp, reduced crashes. As such, the evidence to support Posit Science claims on the Drivesharp website that Drivesharp training "cut crash risk by up to 50%" is not readily apparent. In reality, this claim is based upon one published article on a study that was part of the ACTIVE project and which examined the impact of Insight (i.e., the earlier version of Drivesharp) on collisions. In this study, Ball et al. (2010) randomly assigned nine hundred and eight older drivers to one of three cognitive interventions or a control group. The intervention involved up to 10 sessions of cognitive training in memory, reasoning or speed-of-processing (i.e., UFOV training). The results showed that relative to the control group, two intervention groups (speed-of-processing and reasoning) evidenced lower rates of at-fault collision involvement over a six-year follow-up period. After controlling for other factors including age, gender, race and education both these training groups had about 50% lower per person mile rate of at-fault collisions than the control group. Study authors did not find a significant difference in rates of at fault collisions for the memory group.

In this regard, Simons (2010e) takes issue with the Posit Science statement that Drivesharp reduces collision risk (by up to 50%) reporting that it is not just imprecise, "it's wrong". As evidence of this, he notes that the Ball et al. (2010) study showed significant training effects of speed-of-processing for at-fault crashes but not for all crashes, which includes both at-fault and non-at-fault collisions. In fact, as pointed out by Simons (2010e), "the study did not show any difference in the overall accident rate as a result of training". In other words, the study showed that subjects are 50% less likely to cause a crash but not that their overall crash risk has been reduced by 50%. On the one hand, this study suggests that Drivesharp had a positive effect on at-fault crashes, which were reduced by 50%. On the other hand, there is no clear explanation as to why there was a commensurate increase in non-at-fault crashes, resulting in no significant change in the overall crash rate and eroding any potential benefits derived from Drivesharp training. According to Simons (2010e):

"If training really helps driving, people should be less likely to be in accidents. Period. They should be better able to avoid situations that put them at risk. The results show that they aren't able to avoid such situations as they are in accidents at the same rate as the control group. They are not 50% safer. They are 50% less likely to cause an accident, but by the same token, they are twice as likely to be in an accident that wasn't their fault."

Several other features of the Ball et al. (2010) study also raise concern regarding the generalizability of the results to a population of normal older drivers. The sample of older drivers, for example, comprised 73% females, and although the regression models used in the analyses were adjusted for gender and other factors, it does suggest that results would more likely reflect speed-of-processing training effects on older female drivers than on older male drivers.

Finally, the interventions were led by trainers with small groups of older subjects at the study sites during about 70-minute sessions over a period of five to six weeks. There were 10 initial training sessions for each intervention administered twice a week over a five-week period. This means that the speed-of-processing training was done in a controlled laboratory setting under relatively ideal conditions. In sharp contrast, older drivers typically complete Drivesharp on-line and at home and at their own pace. Based on the positive results from the ACTIVE study, Dr. Ball has been quoted as proposing a follow-up study that would be a randomized design of home-based training relative to a control. She stated that "We want to determine if the training is equally effective when administered at home and evaluate how closely participants adhere to the protocol in this setting" (UAB Center for Aging 2011). As such, it appears that the training effects of the "home-based" Drivesharp program on crashes have yet to be evaluated and remain unknown.

RESEARCH ON OTHER COGNITIVE TRAINING PROGRAMS

Posit Science's Drivesharp is only one of several commercial cognitive training products designed to improve older driver performance. Few of these other products, however, have been assessed to determine if there is a transfer effect of training in specific cognitive abilities to broader cognitive skills used in simulated or real-world driving. At least one evaluation attempted to examine the training effect of the CogniFit Senior Driver Program. Similar to Drivesharp, this is an on-line program developed by CogniFit Inc., another maker of brain fitness software programs, to help aging adults improve and maintain cognitive skills for safe driving. This program provides both an assessment to establish needs and tailored personalized training for 10 driving-related skills, including:

- focus;
- divided attention;
- response time;
- short term memory;
- changing plans;
- width of the visual field;
- visual scanning;
- confidence;
- assessments of speed and distance; and,
- hand-eye coordination.

As individuals train and achieve higher scores, the tasks become more difficult. Given that the program initially involves an assessment of skill levels on these tasks and is personalized based on the results of the assessment, no two training programs are truly alike. Similar to Posit Science, CogniFit emphasizes on their Senior Driver website the science behind the program: "CogniFit Senior Driver program is a scientifically proven and validated brain fitness program designed for people who want to maintain and extend their safe driving skills" (http://www.cognifitpersonalcoach.com/products/cognifit/cognifit-senior-driver). As mentioned previously, however, the literature search identified only one published assessment of CogniFit Senior Driver and it is not referenced on the program website.

Gaspar et al. (2012) recently examined the transfer effects of computer-based training on CogniFit Senior Driver to simulated driving in older adults. For this study, driving performance was assessed on the Beckman Institute simulator at the University of Illinois in traffic environments and experimental scenarios developed using HyperDrive Authoring Suite[2]. Participants included 40 normal older adults with an average age of 74.7 who were assigned to the CogniFit Senior Driver training program (N=20) or the control group (N=20) that played card games on a computer during 16 one-hour sessions. For the CogniFit group, each training session lasted about 30 minutes and participants completed two training sessions per visit to the lab for 16 total hours of

2 HyperDrive Authoring Suite is a software package used to develop driving simulation content, including a library of roads, intersections, vehicles, traffic patterns and landscapes, plus the ability to script specific actions and to collect data.

training. The program took an average of eight to nine weeks to complete.

Participants completed two simulated driving assessments before and after training which included: hazard response tasks (e.g., respond to unexpected events including pedestrians crossing the street, parked cars pulling out, cars turning in front of the participant, and dogs crossing the street); and highway driving tasks (e.g., merging from an off-ramp into traffic, following behind a lead vehicle in high congestion situations). The primary performance measures were response time to the hazard events, steady-state following distance, and safety margins when drivers merged to a new lane.

The results showed that CogniFit training did not significantly reduce response times to hazard events, increase their headway, or modify their safety margins compared to the control group. Based on these findings, Gaspar et al. (2012) concluded that the CogniFit commercial training program did not improve the simulated driving performance of older drivers and that training on cognitive tasks is an ineffective means of improving critical aspects of driving performance. They suggest that training in skills directly related to driving is more likely to produce transfer effects. According to these authors:

"…our results provide evidence that a commercial-based training package did not enhance older driver performance. Older adults looking to improve their driving may be better served by seeking out training programs that provide practice in a driving context than by practicing basic cognitive tasks" (Gaspar et al. 2012, p 148).

RELATED RESEARCH ON COGNITIVE TRAINING PROGRAMS

There are two important research findings emerging from research on older driver programs that can inform our pursuit of effective older driver training programs. First, there is some literature to support the possibility that training on cognitive tasks in a driving context would be more likely to produce improvements in driving performance than repeatedly practicing basic cognitive tasks. In the Roenker et al. (2003) study on the transfer effects of UFOV training (described previously), the authors observed that "collectively, these data present a picture of driving improvements specific to the type of training received" (p.229). As evidence of this, the simulator-trained group showed improvements in lane changes and proper signal use, and these behaviours were expressly practiced during the training.

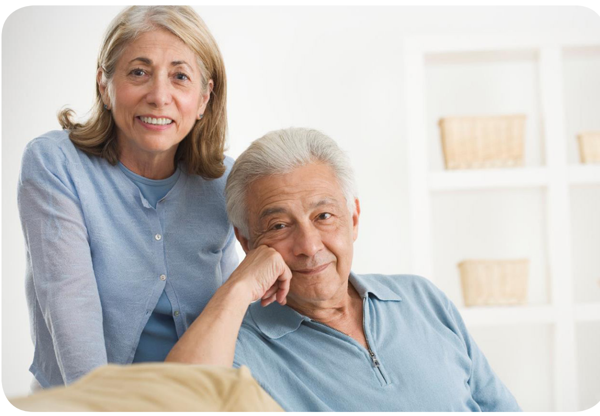
Cassavaugh and Kramer (2009) have also reported that training on computer-based analog aspects of driving (attention, working memory and manual control) improved older driver performance in a simulator. In this study, the training tasks were administered to twenty-one participants with an average age of 71.7 years on a standard PC using a Logitech MOMO racing wheel and pedals to control the position of a tracking cursor. Participants used the wheel to control the horizontal movement of the tracking cursor and they used the accelerator to control the vertical movement of the cursor to approximate the operation of a vehicle. The steering wheel also had six buttons on its face so that participants could respond to working memory and attention tasks. The computer-based training was divided into tasks that depend on attention, visuo-spatial working memory, manual control and their combination in dual-task conditions.

The driving assessments were conducted using the Beckman Institute Driving Simulator at the University of Illinois and driving environments and scenarios were developed with the HyperDrive Authoring Suite software. The simulated driving tasks represented components of driving that were being trained: selective attention, visual working memory, manual control of the car, and the ability to coordinate subsets of these tasks. For example, a visual memory task involved remembering information viewed while driving between different locations (e.g., to note the color of passing vehicles); a monitoring task was used as a measure of visual scanning and object detection during driving.

Participants had two initial driving sessions, followed by eight computer-based training sessions, and two final driving sessions. All participants completed the computer-based training and there was no control group, which is a study limitation identified by the authors because improvements might be due to increased familiarization on the simulator and not to training effects. Results showed that training on relatively simple cognitive analogs of driving can produce significant improvements in simulated driving performance. This was suggestive of transfer effects of training on computer-based driving-related tasks to improvements in simulated driving.

Second, there is also some evidence that active learning methods involving practice and feedback in a contextually face-valid environment (Romoser and Fisher 2009; Romoser 2012) is a more effective strategy than passive training for improving older driver performance. In an initial study by Romoser and Fisher (2009), 54 normal older drivers with a mean age of 77 were assigned to one of three groups:

- active simulator training;
- passive classroom training; or,
- no training.



Ten simulator scenarios on scanning in intersections with peripheral hazards were used for training and the assessment. As well, there was on-road drives in which participants drove their own vehicle and chose their own route which had several turns and required 30 minutes to complete. The active learner group received customized feedback from a replay of simulator and on-road drives they took which were video-taped by cameras mounted around the car and by a head-mounted camera. The passive learning group received a traditional lecture-style training session. Results showed that the active training significantly improved older drivers' scanning in intersections compared to passive training and no training. The authors observed that "active training increased a driver's probability of looking for a threat during a turn by 100% in both post-training simulator and field drivers" but that "those receiving passive training or no training showed no improvement" (p. 652). This study also found that participants in the active learning group compared to those in the passive training group rated the training they received as more effective.

Romoser (2012) recently conducted a follow-up study to determine the long-term effects of active training on older drivers scanning intersections. Older drivers from the initial study (Romoser and Fisher 2009) were re-assessed on-road two years after their training. He found that older drivers in the active learning group still took more secondary looks than they did at baseline prior to training two-years earlier. By contrast, the control group drivers did not significantly change in scanning performance over this two-year period.

This review suggests that, similar to Drivesharp research, other computer-based cognitive training programs that teach specific underlying cognitive tasks do not translate into improvements in the driving performance of older drivers. There is, however, recent and emerging evidence that training on cognitive tasks in a driving context would be more likely to produce improvements in driving performance.

FUTURE DIRECTIONS FOR OLDER DRIVER TRAINING PROGRAMS

Computer-based cognitive training may have a role to play in slowing or preventing declines that are experienced by older drivers. At issue, however, is the type of cognitive training that holds the most promise. While research suggests that such programs are likely effective to improve performance in relation to the specific basic cognitive tasks that are being trained (e.g., visual speed of processing) there is also evidence that these improvements generally fail to transfer to simulated and real-world driving tasks (e.g., hazard recognition while driving).

On its face the literature cited by Posit Science appears to provide impressive and strong evidence that Drivesharp improves older driver performance and reduces crashes. A more careful review of the cited studies as well as the broader literature uncovers a less compelling case for these types of programs. In reality, the statements about the safety benefits of Drivesharp are largely unsupported by the scientific evidence or are overstated. And, the bottom line is that these statements of improved driving performance and crash reductions could have unanticipated and negative consequences for road safety. As observed by Gaspar et al (2012):

"Of particular concern is that commercial programs could lead to older driver overconfidence. A testimonial from the Drivesharp website reads, "75-year-old [man] says DriveSharp has improved his peripheral vision [and] made him feel more confident behind the wheel." Indeed, if these commercial packages fail to improve driving ability, drivers may overestimate their ability and put themselves in overly demanding situations" (p.147).

Computer-based cognitive training programs such as Posit Science's Drivesharp and CogniFit Senior Driver may not improve driving performance and produce safety benefits because they fail to focus on the right set of cognitive functions that are actually associated with specific driving tasks.

As such, while the research does not currently suggest that cognitive-based training programs have significant effects with regard to driver performance or safety, it does provide important insights and guidance in terms of future directions for research and approaches that can better inform the development of more effective tools. In this regard, the relationship between certain cognitive functions and specific driving tasks are not well known. A myriad of cognitive functions might be related to specific driving tasks, such as safe gap selection, but these cognitive functions may be different for other specific driving tasks, such as identifying hazards. As evidence of this, transportation safety researchers at the Transportation Research Institute (IMOB) Hasselt University whom are working with cognitive neuroscientists have recently initiated investigations on the effects of cognitive training and driving in the elderly. In one study, for example, they examined the performance on different driving tasks and related tasks to performance on different cognitive functions and found that each driving task is predicted by other (sets of) cognitive functions (Brijs, personal communication, 2014). Such research into the underlying causal mechanisms between specific driving tasks and cognitive functions is to be encouraged, in that studies may eventually shed more light on the sets of cognitive functions that should be the focus of training programs to improve specific driving tasks.

This also means, however, that it may not always be possible to transfer learning effects to other driving tasks because the set of cognitive functions may differ or, if they are the same, they may need to be applied in different combinations and/or amounts.

There is also emerging evidence that computer-based cognitive training programs that operate in a driving context hold promise for improving older driver performance. And in this regard, Romoser and Fisher (2009) observed that "adult learning theory states adults are more successful with learning strategies that involve active practice and immersion in which they will ultimately be using the skills that they are learning" (p. 665). Potter (2011), in the study described previously, also referenced this adult learning literature (Knowles et al. 2005) which "supports the idea that a task that is similar in nature would show the most robust improvements" (p. 85). And, Gamache et al. (2012) have recently observed that:

"According to a practice-specificity approach, if the benefits are to transfer on the road, they must be acquired in a driving-specific context…That is a driving training program should involve conditions that are as close as possible to the actual driving conditions"(p. 372).

The available research reviewed in this paper suggests that new computer-based and simulated driving-specific training programs hold promise and are more likely to have transfer effects that improve older driver performance than those programs targeting basic underlying cognitive functions that fail to capture the complexities of driving and the important driving abilities that need to be mastered and maintained to drive safely. In this regard, a driving context approach has been taken by Lifelong Driver, a computer-based training program for older drivers, developed by ADEPT Driver. The development of this program was guided by a panel of experts in traffic safety, gerontology, occupational therapy, psychometrics and instructional technology. Based on background research on older driver crashes, the program focusses on major causes of collisions of older drivers, including:

- judging safe gaps in traffic, especially when making left-hand turns at intersections;
- determining adequate distances from other vehicles when merging and making lane changes;
- detecting hazards and dealing with distractions while driving;
- identifying and remembering relevant objects while driving; and,
- dealing with complex driving environments, like busy intersections and parking lots.

The program takes a driving context approach by using video of real life driving situations in repetitive computer-based learning exercises, at-home activities and optional on-road practice of specific driving skills to address these crash factors. The simulated driving exercises and other learning program materials focus on: where seniors are most likely to be driving; where they are most likely to be crashing; and where they are most likely to be overrepresented in crashes.

A review of the Lifelong Driver program suggests that these training exercises have face and content ("logical") validity (http://www.lifelongdriver.com). This program, however, still uses point of view driving simulation and the keyboard and mouse for navigation, which may or may not translate into better driving performance of older drivers and improvements in road safety.

There is a need to develop, and rigorously evaluate, new computer-based programs, such as the active simulator training used by Romoser and Fisher (2009) and Lifelong Driver, that adopt a more "practice-specific" approach in a realistic driving context to ensure that the learning transfers not only to the underlying cognitive abilities being trained, but also and more importantly, to better on-road driving, and ultimately to fewer collisions involving older drivers.

ABOUT THE TRAFFIC INJURY RESEARCH FOUNDATION (TIRF)

The mission of the Traffic Injury Research Foundation (TIRF) is to reduce traffic-related deaths and injuries. TIRF is a national, independent, charitable road safety research institute. Since its inception in 1964, TIRF has become internationally recognized for its accomplishments in a wide range of subject areas related to identifying the causes of road crashes and developing programs and policies to address them effectively.

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Dr. Shawn Marshall is a physician specializing in Physical Medicine and Rehabilitation (Physiatrist). He is the Medical Director for Acquired Brain Injury Rehabilitation at the Ottawa Hospital Rehabilitation Centre where he manages both in-patients and out-patient clinics. Dr. Marshall has a Master's degree in Clinical Epidemiology and is an Associate Professor at the University of Ottawa in the Department of Medicine. Driving and disability, specifically older driver research, is one of the main areas of clinical research interest for Dr. Marshall. His driving research interests have focused on conditional licensing as well as assessing medical fitness to drive. Dr. Marshall was a founding co-investigator for the Canadian Driving Research Initiative for Vehicular Safety in the Elderly (Candrive) which was funded from 2002-2007 by CIHR as a New Emerging Team. The Candrive research team worked to develop a national network of researchers and partners focusing on older driver research with the aim of improving safety and fair assessment for older drivers. The Candrive research program has since progressed to The CIHR Team in Driving in Older Persons (Candrive II) Research Program (2008-2013) where Dr. Marshall is a principle co-investigator.

The review of Drivesharp research has been greatly facilitated by a series of articles entitled "Science or sciencey" that appeared on the blog of Daniel Simons, one of the authors of "the invisible gorilla" (Chabris, and Simons 2010) in September and October, 2010. In these articles, Dr. Simons examined the statements made by Posit Science about Drivesharp and the research underlying it as a case study of the use of science in marketing (see: Simons 2010a, b, c, d, e.). We appreciate Dr. Simons' contribution to our field and the unique insights he provided on the scientific evidence behind Drivesharp.

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The opinions, findings, and conclusions expressed in this report are those of the authors and do not necessarily reflect the views of any individuals that peer-reviewed this report.

METHOD (web-based and literature searches)

Journals - Accident Analysis and Prevention; Alzheimer's Disease and Associated Disorders; American Journal of Occupational Therapy; American Journal of Public Health; Clinics in Geriatric Medicine; Human Factors; Injury Prevention; International Journal of Geriatric Psychiatry; Journal of Gerontology; Journal of Occupational Therapy; Journal of Safety Research; Journal of the American Geriatrics Society; Journal of the American Medical Association; Journal of the International Neuropsychological Society; Neurology; Traffic Injury Prevention; Transportation Research; Transportation Research Record.

Libraries - TIRF Library; Austroads (Australian Department of Transportation); Canadian Association of Road Safety Professionals (CARSP); SWOV Institute for Road Safety Research; IMOB at University of Hasselt; Insurance Institute for Highway Safety (IIHS); National Highway Traffic Safety Administration (NHTSA); University of Michigan Transportation Research Institute (UMTRI); University of North Carolina Highway Safety Research Center (HSRC).

Proceedings - Association for the Advancement of Automotive Medicine; Fit to Drive; Traffic and Transport Behavior Psychology; Transportation Research Board.

Search Engines and Online Catalogues - Google; Medline; Pubmed; Safety Lit; Sage Journals; Science Direct.

GLOSSARY

Attention Network Test (ANT) - A test that is designed to evaluate alerting, orienting, and executive attention within a single 30-min testing session that can be easily performed by subjects.

Choice reaction time - The reaction time for a task in which a subject has to make one of two or more choices – e.g. a task defined in terms of three components: 1) relevant stimulus set (stimulus properties that one must discriminate in order to determine what to do); 2) response set (actions that one may have to perform); and 3) mapping instructions (which associate each element in the stimulus set with an element in the response set).

Cognitive analogs of driving - Tasks that are related to driving skills such as the lateral/longitudinal control of a vehicle, peripheral detection/discrimination tasks and situation awareness.

Dangerous manoeuvres - Driving actions taken by the subject which result in either the driving instructor having to take control of the car or other vehicles being forced to alter their courses in order to avoid a collision.

Raven's Progressive Matrices - A neuropsychological test which measures fluid intelligence abilities, including problem solving, pattern completion, and abstract reasoning. It is comprised of 60 visual analogy multiple-choice problems. Each problem presents an image with a missing component, and the subject must choose one of six item options that will best fill the missing segment to complete the larger pattern.

Selective attention - The ability to localize targets in an embedded condition relative to localization performance for targets presented in isolation.

Simple reaction time (SRT) - The time required for a subject to initiate a prearranged response to a defined stimuli – e.g., a test in which a subject watches an arrangement of six coloured lights that are located on the top panel of the driver's unit. Colour-matched pairs of these lights blink in a random order and the participant must brake as quickly as possible when two red lights (simulated brake lights) are illuminated. SRT is measured by the elapsed time between the onset of the brake lights and the release of the accelerator pedal.

Simulator sickness - A condition experienced by some drivers which may result in nausea, disorientation, dizziness, headache, and/or difficulty focusing when in a simulator (especially fixed base simulators).

Speed of processing training - The practice of visual attention skills and the ability to identify and locate visual information quickly in increasingly demanding visual displays.

Steady state following distance - Measure of driving performance where the subject follows behind a lead vehicle in the same lane for an extended period.

Strategic driving skills - These include cognitive and executive function tasks (e.g., divided attention, anticipating hazards, speed of processing).

Tactical skills - These include visual search and scanning tasks (e.g., scans environment, blind spot checks); vehicle positioning tasks (e.g., gap selection, following distance, lane changes); and vehicle handling skills (e.g., appropriate speed, smooth steering, smooth acceleration, speed maintenance).

Trailmaking tests A,B,C,D - A neuropsychological test of visual attention that requires participants to draw a line to connect 25 consecutive targets on a sheet of paper.

Transfer effects - Role that training in specific cognitive functions plays to improve functioning in related, and unrelated, cognitive realms.

Useful Field of View (UFOV) - The area from which one can extract visual information in a brief glance without head or eye movement. The limits of this area are reduced by poor vision, difficulty dividing attention and/or ignoring distraction, and slower processing ability.

Visual working memory task - A task which measures a subject's visual working memory (VWM) or one's ability to hold visual information in mind for a few seconds. It can be measured by such tasks as the Clock task.

Wheel reversal rate - A measurement of the total number of reversals per period of measurement.

1-back delayed digit recall test - A test in which a sequence of one-digit numbers is read aloud, and the subject is asked to repeat the digit that immediately preceded the one currently being spoken.

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