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The Ecology of Cognitive Training and Aging

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THE ECOLOGY OF COGNITIVE TRAINING AND AGING

A Dissertation Presented

by

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ABSTRACT

THE ECOLOGY OF COGNITIVE TRAINING AND AGING

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Older individuals represent the fastest growing portion of the population in the United States, and are threatened by the loss of mobility and independence. The present study examined the relationship of a computer-based training program, specifically Posit Science Cortex™ with InSight DriveSharp™, and performance on neuropsychological measures and an on-road driving paradigm in a normal aging sample. Participants, ranging in ages 60-75 and randomly assigned to the treatment group, completed the DriveSharp™ as did, subsequently, a wait-list control group. Identical neuropsychological and on-road assessments were conducted at each visit. Neuropsychological assessment of visual attention included the Useful Field of View test (UFOV; Edwards, Vance, et al., 2005), Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002), and the Trailmaking test (Franzen, Paul, & Iverson, 1996; Reitan, 1986). Results indicated improved performance on neuropsychological measures of attention after intervention. Analysis of the waitlist control groups across three visits, revealed possible practice effects for the ANT. However, this was not true for the UFOV test, which, revealed significant improvements between visits 1 and 3, suggesting that practice effects may not be a factor. During the on-road driving tasks,

standard deviations of horizontal and vertical eye gaze were measured while participants completed auditory and visual working memory tasks. Given the improvements within the waitlist control group across three visits, it is unclear whether the improvements are resulting from the training or rather comfort in the vehicle. Overall results indicated there were trends in increased standard deviation of both horizontal and vertical eye gaze during the auditory working memory task. More robust improvements were seen during the visual working memory exercise, with significant improvements in horizontal gaze. These findings suggest more horizontal scanning behavior and possibly an increased field of view while driving. These results provided evidence that cognitive training may improve not only performance on neuropsychological tests but also on more ecologically valid outcome measures of driving. However, limitations of the current study may be addressed in future research by using a larger sample size, providing better control of practice effects on neuropsychological testing, and incorporating more direct measures of driving.

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INTRODUCTION

Advancements in medical sciences and technology have resulted in enhanced health with advanced age; however, becoming more apparent are declines in cognitive ability. For the foreseeable future a burgeoning aging population is going to be faced with difficulties in everyday tasks thwarting their independence. The need for assistance in later life places a strain, both emotionally and financially on individuals, their families, and society. It is these very points that challenge current definitions of cognitive health, which is "the development and preservation of the multidimensional cognitive structure that allows the older adult to maintain social connectedness, an ongoing sense of purpose, and the abilities to function independently, permit functional recovery from illness or injury, and cope with residual functional deficits (Hendrie, et al., 2006, p. 13)." A myriad of cognitive training interventions have been designed with that goal in mind.

1.1 Specific Aims and Hypotheses

Aim #1: To examine neuropsychological improvement following intervention with a commercial brain-training software program, Posit Science Cortex™ with InSight Drive Sharp™. Research has demonstrated improvement using cognitive training programs in normal aging individuals (K. Ball, et al., 2002; K. Ball, Edwards, & Ross, 2007; Willis, et al., 2006; Fredric D. Wolinsky, et al., 2006). A community sample of individuals ages 60-75 who are of normal cognitive aging (MMSE greater than 26) were assigned to a training software or waitlist control to determine the efficacy of brain-based training software on visual attention. *Hypothesis 1:* It was hypothesized that individuals assigned to the cognitive training intervention would show significant improvements (alpha = 0.05) in measures of visual attention as assessed by the Useful Field of View test (UFOV; Edwards, Vance, et al., 2005), Attention Network Test (ANT; Fan, McCandliss,

Sommer, Raz, & Posner, 2002), and Trailmaking test (Franzen, Paul, & Iverson, 1996; Reitan, 1986).

Aim #2: To examine improvements in on-road driving performance following intervention with a commercial brain-training software program, Posit Science Cortex™ with InSight Drive Sharp™. Studies examining on-road driving performance thus far have not provided comprehensive results and lack ecological validity. This study assessed improvements in driving performance using an instrumented, on-road vehicle developed by the Massachusetts Institute of Technology (MIT). A community sample of individuals, ages 60-75 who were of normal cognitive aging (MMSE greater than 26) were assigned to either training software or waitlist control. Eye-tracking data collected while driving assessed visual search and by proxy divided attention. *Hypothesis 2:* It was hypothesized that individuals assigned to the cognitive training intervention would show a significant improvement (alpha = 0.05) in of the allocation of attention to the road as assessed by horizontal and vertical gaze dispersion (eye-tracking) (Reimer, Mehler, Wang, & Coughlin, 2010). *Hypothesis 3:* It was hypothesized that under instances of divided attention, the decrease in the visual field measured while driving would be less after training with the DriveSharp™ intervention.

1.2 Neuropsychology of Aging

Research has shown that as individuals grow older, crystallized abilities, which are defined by the ability to use skills, knowledge, and experience, are preserved and may even improve with age. There is, however, a rapid early decline in fluid ability (G_f), which is classified by abilities such as problem solving, learning, and pattern recognition (Maitland, Intrieri, Schaie, & Willis, 2000), particularly in complex and demanding environments. G_f has a hereditary component and unique to it is the fact that it is not influenced by education and socialization (Baltes, Staudinger, & Lindenberger, 1999; Cattell, 1963). Processing speed has a major impact on higher-level cognitive abilities (Bors & Forrin, 1995; Timothy A. Salthouse, 1985; T. A. Salthouse, 1996) and is extremely vulnerable to neurological insult and the aging process.

With aging, individuals are thought to have reductions in cognitive efficiency (Vernon, 1983). This is supported by neuroimaging, which has shown that cognitive

efficiency is the result of interactions between different brain regions such that slower individuals require more prefrontal executive control than faster individuals to perform a processing speed task successfully (Rypma, et al., 2006). At the foundation of this theory is processing speed. The benefit of processing speed as it relates to cognitive efficiency is that it does not appear to depend on motor speed (Timothy A. Salthouse, 1992) or working memory (Timothy A. Salthouse, 1991). Closely related to processing speed is attention, particularly visual attention as age-related declines in both visual and processing speed are commonly observed (Hartley & Kieley, 1995; Madden, et al., 2007; T. A. Salthouse, 1996).

Visual attention is a multi-faceted cognitive domain. It requires an individual to focus on the selection of a region of interest in the visual field, the selection of feature dimensions and values of interest, the control of information flow through the network of neurons that constitutes the visual system, and the shifting from one selected region to the next in time (Tsotsos, et al., 2001). Specifically, the pre-attentive system uses rapid parallel processing over large spatial areas to alert or orient the attentive system to locations in spaces where the relevant or changing information is (Tsotsos, et al., 1995).

Older adults show an age-related deficit in performing dual tasks (Hartley, 2001) and relates to three sources: general slowing, process-specific slowing, and the use of a more cautious task coordination strategy during dual tasks (J. M. Glass, et al., 2000). They have also been shown to have more difficulty preparing for multiple tasks than they do either switching between two tasks or performing multiple tasks concurrently (Cepeda, Kramer, & Gonzalez de Sather, 2001; Kray & Lindenberger, 2000; Mayr, 2001).

A theory of visual attention, call the premotor theory, states that control of goal-directed movements and the control of attention are closely linked, because they are implemented by common structures (Rizzolatti, Riggio, & Sheliga, 1994). It states that covert attention, which is the act of mentally focusing on one of several possible sensory stimuli, is a result of activity within the motor systems responsible for the generation of a saccade. An attentional shift, like cognitive efficiency, happens because the human brain is limited in its ability to process information and multiple processing happens at a cost. Posner's introduction of a cue-detection paradigm facilitated this work and has thus been used to investigate the relationship between eye movements and attention shifts. Not only do attentional shifts influence the timing of microsaccades (Engbert & Kliegl, 2003) but they also alter neural activation (Nobre, Gitelman, Dias, & Mesulam, 2000; Nobre, Sebestyen, & Miniussi, 2000). Within this framework, attention is a by-product of the action of motor systems, and attentional effects can be associated with different motor systems or spatial coordinates. Multiple studies have shown activity evident in the frontal cortex, concentrating in the precentral sulcus, the parietal cortex (specifically in the intraparietal sulcus), and in the lateral occipital cortex for both overt and covert attention shifts (Beauchamp, Petit, Ellmore, Ingeholm, & Haxby, 2001). With these theories as the foundation, visual attention training programs target these areas with the aim of improving the efficiency of these networks.

1.3 Cognitive Training Programs

The brain fitness industry is growing rapidly. It is estimated that approximately 400 to 500 facilities for older adults in the United States now offer some type of computerized brain fitness program to complement recreational and therapeutic activities.

Individual consumer purchases for at-home use are increasing rapidly as well (Van Pelt, 2008). The purchase, however, can be quite daunting as programs boast various improvements. Despite studies such as the "Advanced Cognitive Training for Independent and Vital Elderly" (ACTIVE; Willis, et al., 2006) and the SKILL (the Staying Keen in Later Life) clinical trials demonstrating improvements following training (Edwards, Wadley, et al., 2005; Owsley, Sloane, & McGwin, 2002), meta-analysis reveal training programs have failed to delay or slow of progression in brain disease (Papp, Walsh, & Snyder, 2009). As a result, more research is desired so that the aging adults can make more informed decisions about engaging in interventions.

Previously, much of the research on cognitive intervention revolved around developing compensatory strategies. However, a major limitation of this research is that people do not seem to transfer strategies into use in their daily lives (Kramer & Willis, 2002; Neely & Bäckman, 1995; Willis & Schaie, 1994). Subsequently, research has shown that older adults are able to overcome cognitive deficits through training (Bherer, et al., 2005; Buschkuehl, et al., 2008). Although improvements in cognitive abilities have been observed in a myriad of domains, such as on measures of episodic memory and inductive reasoning, the current study focuses on speed-of-processing training as it relates to visual attention since it has shown the most robust improvement (K. Ball, et al., 2002; Edwards, Vance, et al., 2005).

There are a couple of computer-based platforms for cognitive training on the market based on the premise that systematic increases in task difficulty will challenge the user to adapt, and subsequently improve. Posit Science Cortex™ with InSight™ DriveSharp™ program, inspired by Dr. Karlene Ball's Visual Awareness program, has

shown improvements in visual attention. This program aims at improving Useful Field of View (UFOV), which measures the speed at which one can rapidly process multiple stimuli across the visual field. A caveat, however, is that the UFOV training resembles the UFOV test, which may lead to learning of the specific test and not translate to other domains. To my knowledge, this has yet to be mentioned by other researchers (further elaboration on this in the discussion section). Both UFOV and the Attention Network Task (ANT) is considered a measure of attentional resources and their spatial distribution (K. K. Ball, Beard, Roenker, Miller, & Griggs, 1988) (Weaver, Bedard, McAuliffe, & Parkkari, 2009). Specifically, there is concurrent validity between the UFOV total score and the overall mean, conflict efficiency, and overall percentage of errors on the ANT. The utility of such a measure for visual attention stems from it being affected by multiple factors such as visual sensory function (Owsley, Ball, & Keeton, 1995), processing ability, divided attention, and the ability to ignore distracters (K. K. Ball, Roenker, Bruni, & Enns, 1990).

While UFOV may not be a reliable measure of improvement, other measures of fluid intelligence may. While training has shown time and again that it can improve performance on similar tasks, transfer to other subdomains of fluid abilities has not been shown unequivocally. More recently, however, studies have shown that working memory tasks can improve perceptual reasoning (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) and visual working memory (Buschkuehl, et al., 2008). Ultimately, demonstrating that plasticity in older adults is strong enough to improve abilities in transfer tasks and not just the trained ability.

1.4 Ecological Validity

Training programs advertise improvement in a myriad of cognitive domains and generally these are measured by neuropsychological tests. Despite neuropsychologists claiming that the instruments administered possess high test reliability and validity, they are often forced to admit that a particular test score or set of test scores might not accurately predict how a patient would function in his or her environment. It is this and other methodological limitations that diminish the significance of the cognitive training improvements.

To this end, it is imperative to look at an ecologically valid means of assessing improvement. Ecological validity is the degree to which results obtained in a controlled experimental condition can be generalized to naturalistic or real world environments (Tupper & Cicerone, 1990). The importance of addressing the improvement in everyday activities, as opposed to improvements in the trained domain, is that research has shown that declines in cognitive abilities lead to difficulties with basic activities of daily living (ADLs). Given that functional declines are associated with increased likelihood of nursing home placement (F. D. Wolinsky, Callahan, Fitzgerald, & Johnson, 1993) and depression (Fonda, Wallace, & Herzog, 2001; T. A. Glass, Kasl, & Berkman, 1997; Marottoli, et al., 1997), finding an ecologically valid means of measuring change and improvement is necessary.

The motivation for this new wave in assessment is two-fold: 1) Many of the tests are culturally unfair and not valid measures of cognitive abilities for every individual; and 2) the results do not translate to real-life situations. As a result, for a test to be

ecologically valid, the methods, materials, and setting of the study must approximate the real-life situation that is under investigation (Brewer, 2000). The field needs to address these issues in order to provide more accurate and helpful information to individuals. The use of driving, as an ecological measure of improvement from speed-of-processing training, shows potential because the loss of driving abilities carries a large psychosocial impact, it relates well to the visual attention construct, and, currently there is no appreciable link between neuropsychological tests, training, and measureable real-life improvement.

1.4.1 Driving and its Psychosocial Impact. In general, older drivers are safe drivers and have shown to engage in a number of self-regulation behaviors. This includes avoiding busy highways, left turns, and travelling at peak times. Generally, individuals begin to make changes in regulatory behavior early than typically perceived (Baldock, Mathias, McLean, & Berndt, 2006; Blanchard & Myers, 2010). Crashes per vehicle mile travelled (VMT) for head-on, rear-end and single car collisions either stay the same or decrease after the age of 70 (Bryer, 2000; Ryan, Legge, & Rosman, 1998). In contrast, the crash rate per VMT for angled impacts in which the front of one car collides with the door of another increases significantly after the age of 70 (Abdel-Aty, Chen, & Radwan, 1999; Bryer, 2000), especially making left turns or merging (Caird & Hancock, 2002). Data such as this lead legislators with the onerous task of determining who can and cannot drive.

So often the act of driving is questioned as either a right or a privilege. While this is not the question guiding this research, its psychosocial impact is. Until one loses the ability to drive, its impact often goes unnoticed. A cohort of older individuals from a

rural environment who ceased driving, reported lower health status, increased functional disability, poorer vision, and decreased social support (Horowitz, Boerner, & Reinhardt, 2002). Arguably, one cannot determine whether it was driving that led to those deficits or whether the deficits led to the decision to cease driving. But while the reasons vary, at the foundation is the impact driving cessation has on an individual's psychological well-being.

Those who stop driving have an increased rate of depression or depressive symptoms (Fonda, et al., 2001; T. A. Glass, et al., 1997; Marottoli, et al., 1997), and adults ages 63 to 97, who stopped driving were four to six times more likely to die within three years (Edwards, Reynolds, Ross, & Perkins, 2009). Data such as this gives credence to reports such as one man's explaining the impact of driving cessation on his father: "My father died at 85, but he really died at 80. He was the most active, funny, enthusiastic person, just a jewel. We tried everything possible to offset that loss of freedom, that quality of life, but there was nothing we could do. [Seeing him] just watching TV and eating, waiting to check out was heartbreaking (Mohn, 2008, p. AU2)." With that, it is the mission of a various fields to establish a means of maintaining cognitive health in our aging population. Brain fitness is just one of these.

1.4.2 Visual Attention and Driving. Visual attention is the primary cognitive construct being taxed during driving (Reimer, 2009; Reimer & Sodhi, 2006; Sodhi, Reimer, & Llamazares, 2002). It does so by requiring the driver to have his or her attention directed to relevant objects (preattentive search) all the while needing the ability to switch attention voluntarily between objects (attentive search). Studies have suggested that effective scanning of the environment is important for safe driving. This ability

relates to inhibition of return (IOR), a well-known mechanism of human perception that biases attentional orienting to novel locations in the environment (Posner & Cohen, 1984). IOR is thought to play a major role in healthy cognition, in general, and efficient and adaptive visual search (Klein, 2000). It prevents attention from being locked into a particular location; it protects against redundant, distracting sensory information; and it presets perception to favor novel locations for foraging and exploration over already sampled, checked, and explored sources that are likely barren.

In order to drive safely, one needs to engage in optimal switching abilities and disengage their attention appropriately. Significant relationships exist between accident rates and switching efficiency in laboratory tests (Parasuraman & Nestor, 1991). IOR is pertinent to driving because as an individual drives, he or she is constantly shifting attention around the visual field from various objects and locations. Not only that but as a construct, IOR is relevant for older adults particularly because the neural structures underlying it remain intact as an individual ages (Castel, Chasteen, Scialfa, & Pratt, 2003). In evaluating differences between older and younger adults, McCrae & Abrams (2001) found that both groups show similar location-based IOR but not object-based IOR indicating that there are age-related deficits in tracking moving objects. This has clear relevance in the visual attention abilities, particularly in the dynamic environments required of everyday living, because of how driving necessitates that these skills be sharp.

One study indicated that better IOR performance predicted overall driving evaluation scores, as well as the number of errors in scanning the environment, which was defined to include failure or inadequate checking of mirrors, and scanning the

surroundings while driving, including intersections (Bedard, et al., 2006). This information relates well to data suggesting that older adults are slower to make driving decisions (e.g. route selection) than are younger adults; however, if they are given sufficient time the quality of their decisions do not decline (Walker, Fain, Fisk, & McGuire, 1997). It is these moments, which occur unexpectedly during the drive and require a rapid response, that have been associated with increased crash risk in older adults. Secondly, it was found that a form of speed-of-processing training led to greater situational awareness (number of hazards detected) in a simulated driving task (Sifrit, Chaparro, Groff, & Stumpfhauser, 2001).

However, as individuals grow older, the capacity with which they can perform these tasks decreases and with that, so does safety. When performing two tasks, like driving and talking, it requires the brain to have to areas working concurrently. Related to the previously mentioned theory of cognitive efficiency, Christopher D. Wickens (2008) proposed a multiple resource model of mental workload. His four dimensions include stages of processing (e.g., perceptual versus cognitive), codes of processing (e.g., visual versus verbal), modalities within perception (e.g., visual versus auditory), and lastly, visual channels (e.g., focal versus ambient vision). Like cognitive efficiency, the foundation of this model rests on the idea that the brain can only process a limited amount of information efficiently. This particular model highlights that to the extent that two tasks use different levels along each of the first three dimensions, timesharing will be better. The relationship of this theory to older drivers allows for an understanding for how an individual can manage driving while concurrently using a cell phone or other in-vehicle technology. As was reported in the New York Times, for older individuals, “As

technology grows in automobiles, it is a concern that if systems require a response or attention, it may cause cognitive overload or distraction (Mohn, 2008, p. AU2)." Together, it becomes imperative to not only assess visual attention distribution during tasks but also during the spectrum of divided attention in order to determine the validity of an evaluation measure.

It is important to consider the neural network of driving as well as it relates to driving. Driving requires visual and spatial processing which the occipital and parietal lobes are responsible for – the same areas involved in visual attention. Research has shown that just as neural efficiency is reduced in older adults (Rypma, et al., 2006), so is the neural activity in young drivers performing dual tasks (Just, Keller, & Cynkar, 2008). Given the improvements in technology and number of distractions while driving, coupled with the natural changes in attention capacity, older individuals are left at a disadvantage and questionable safety on the road.

1.4.3 Neuropsychological Assessment. Neuropsychological assessment poses two problems given the question of determining an ecologically valid measure for improvement in cognitive training: 1) practice effects of repeated administration of test, and 2) the translation of impairment on cognitive testing to real-life tasks. Both problems have been longstanding criticisms in the field of neuropsychological assessment.

To measure improvement from cognitive training or driving ability, the standard practice is to administer a combination of in-person and pencil-and-paper neuropsychological tasks. The ACTIVE trial relied on the Repeatable Battery for Neuropsychological Assessment (RBANS; Randolph, 1998), which is a reliable screening measure of cognitive abilities. It also has alternate versions, which allowed for

re-administration in as little as six months. However, to look at constructs such as visual attention, other tests need to be administered.

Tasks designed to measure processing speed are designed to be simple so that differences in individual reaction time can be attributed to execution of the task and not to other cognitive domains such as crystallized abilities or strategies. At the same time, however, they are complex enough to require more than simple sensorimotor operations. However, one of the major limitations to measuring improvement from training that boast improvement in a limited number of hours is that the neuropsychological measures are not designed to measure improvement in short time frames. Given that, they are susceptible to practice effects, particularly in instruments with a speeded component or those having a single, easily conceptualized solution (McCaffrey, Duff, & Westervelt, 2000). The advantage then to real-life measures of improvement (e.g. eye tracking in a dynamic environment during driving) is that it lends itself to more functional comparisons (Reimer & Sodhi, 2006; Sodhi, et al., 2002). Unfortunately, the practice effects that occur in eye gaze have not been fully developed.

The Useful Field of View (UFOV) test has demonstrated improved visual attention after cognitive training (K. Ball, et al., 2002) and as a good predictor of crash risk (K. Ball & Owsley, 1993; K. K. Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Owsley, et al., 1998). However, the UFOV test resembles the cognitive training program on the screen, and does not truly measure driving abilities. The Attention Network Test (ANT), has been correlated with the UFOV task during driving simulation studies as well as a predictor of crash risk (Weaver, et al., 2009). The combination of simulator studies

and use of computer measures as proxies for driving abilities lack much of the construct agreeability one looks for in ecological validity.

Attempts have been made to address the limitation of neuropsychological tests' abilities to translate to real-life abilities. A plethora of research has been devoted to this. Neuropsychological tests such as the Motor Free Visual Perception Test (MVPT; Colarusso & Hammill, 1996), which is used to measure visual perception, have correlated to driving performance (Korner-Bitensky, et al., 2006; B. L. Mazer, Korner-Bitensky, & Sofer, 1998; Staplin, Lococo, Gish, & decina, 2003). Much of the clinical research as it relates to driving looks to executive function measures, which look at an individual's ability to switch, plan, and organize. Specifically, Trailmaking B (Reitan, 1986) and Color Trailmaking 2 (D'Elia, Satz, Uchiyama, & White, 1994) are used to determine driving competence (Elkin-Frankston, Lebowitz, Kapust, Hollis, & O'Connor, 2007; Grace, et al., 2005; Whelihan, DiCarlo, & Paul, 2005). Staplin et al. (2003) found that those who exceed 180 seconds on Trailmaking B were found to have a significantly higher crash risk.

1.4.4 Driving As a Potentially Ecologically-Valid Measure. Driving lends itself as an ideal measure of an ecological transfer task because: 1) Driving represents one central example of a complex everyday behavior that ranges from highly automatic routines of navigating familiar streets to demanding actions requiring effort, such as making left-hand turns in traffic; and, 2) The role of visual attention impairment in older individuals has been established and may be related to poorer driving abilities and higher crash risk (K. Ball & Owsley, 2000; Clay, et al., 2005).

Roenker et al. (2003) suggest that interventions to reverse visual processing impairments may ultimately assist in reducing motor vehicle accidents and mortality in the elderly. Using a simple speed-of-processing intervention, Ross (2008) suggested that high-risk (reduced UFOV) older drivers could increase their UFOV and subsequently lowers their crash risk. Generally, improvement of UFOV was based on pre- and post-UFOV test performance. However, a limitation to this work is that these studies make arguments based on certain measures and research participant pools, which are not necessarily generalizable. Despite the methodological limitations the studies show a trend for improvement in driving performance from UFOV training.

Although some researchers contend that transfer alone to real-life activities demonstrates ecological validity of the training, the research has not demonstrated this unequivocally. The driving research relies heavily on driving simulators as they provide a means of conducting safe, controlled, replicable research protocols. It has been used extensively to study driving safety (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010; H. C. Lee, Lee, & Cameron, 2003) and various aspects of driver behavior (Reimer, D'Ambrosio, Coughlin, Kafrissen, & Biederman, 2006). However, driving simulators pose a disadvantage in the research when the desired behavior does not translate well in the real world. In fact, McAvoy et al. (McAvoy, Schattler, & Datta, 2007) demonstrated that mean speeds in the simulator did not provide an accurate estimate of speeds in the field. Other studies have shown that there is some concurrent validity between simulator and field studies when looking at basic task performance (e.g., reaction time) and visual distraction as measured by glance analysis (Ying, et al., 2010), as well as driving behavior (Godley, Triggs, & Fildes, 2002).

In particular, the face validity of the driving simulator and protocol used in Roenker et al. (2003) resembles actual driving. The simulator was constructed using a 35-mm projection system and five-piece driving console (steering wheel, brake, accelerator pedals, and an instrumented dashboard). Although the setup has some degree of similarity to a vehicle completed during the protocol 1) braking when two red lights were simultaneously illuminated (simulating brakes lights) and 2) reacting only to road signs (pedestrian, bicycle, right and left arrows) when there was a red slash through them can be considered basic derivations of psychomotor assessments. These assessments do not provide objective measures of on-road improvement, and to date the literature on such measures in relation to cognitive training improvement is sparse. The aforementioned study appears to be the basis for the DriveSharp™ advertising statements on positscience.com such as “Speeds up visual processing and increases ‘useful field of view’ so drivers see more of the road with each glance”, “Decreases reaction time, so drivers can stop 22 feet sooner at 55 mph”, and “Cuts at-fault crash risk by 50%”.

There is a burgeoning research on the validity of on-road driving assessments that use eye tracking in dynamic environments (Mehler, Reimer, & Coughlin, 2010; Reimer & Mehler, in press; Reimer, Mehler, Coughlin, Godfrey, & Tan, 2009; Reimer & Sodhi, 2006). With that, the proposed research seeks to extend the literature by addressing more fully the measurement of improvement in these studies. Driving, specifically an on-road assessment with eye tracking would provide a good transfer task to assess cognitive training. It does so by looking at what an individual does and not what he or she can do, which is central to ecological validity (McCue & Pramuka, 1998).

CHAPTER 2

METHODS

2.1 Participants

Individuals ages 60-75 who speak and understand English with a valid driver's license were recruited from the metro Boston area either via advertising or were existing members of the MIT AgeLab's participant database. The final sample included: 47% female participants, 91% White with the remaining minority representation including Asian and Black, 88% right-handed, and averaging 17.1 (*SD* = 2.64) years of education.

Figure 1 illustrates participant flow through the study. Following the initial screening process, participants were randomly assigned to either the Posit Science Cortex™ with Insight Drive Sharp™ training, heretofore called DriveSharp™, or the waitlist control group. Twenty participants were assigned to DriveSharp™ and 17 to the waitlist control group. Four of the 20 participants assigned to the DriveSharp™ intervention discontinued. One participant cited boredom with the training, one took ADHD medication before his second evaluation, and the others encountered computer difficulties with installing the software, leaving 16 completers for the immediate DriveSharp™ group. One individual assigned to the waitlist control group discontinued due to scheduling difficulties. Taken together, 16 of the 20 participants who were offered the immediate DriveSharp™ completed, representing 80% of the sample and 16 of the 17, representing 94% of those randomized to the waitlist control group completed.

2.2 Design

A randomized, waitlist controlled design was used. The dual baseline approach was used as it is considered a viable means of reducing and evaluating practice effects in studies with multiple assessment points (McCaffrey, et al., 2000). The design included two groups (waitlist control and immediate intervention) and testing at two or three time points for intervention and waitlist control, respectively. The intervention group began the intervention while the waitlist control group began the intervention after 2 weeks time (the time to complete the intervention). Figure 2 describes the research participant procedures.

At each time point, participants completed driving and neuropsychological assessments. For the latter, they completed the UFOV and ANT tests (more details below) at each time point whereas the Trailmaking tests were only administered before and after the intervention. Waitlist controls did not engage in any computer type exercises as past research has shown that there is no difference between waitlist controls who engage in a non-training computer-based activity (referred to as an active control) and those who do not (Edwards, Wadley, et al., 2005; Vance, et al., 2007).

2.3 Intervention

The intervention is a computer-based cognitive training program called Posit Science Cortex™ with Insight Drive Sharp ™. For specifics on the computer requirements please refer to Appendix A. The training encompasses two engaging tasks:

1. Jewel Diver™ – In this computer simulation, the participant acts as a deep-sea diver tracking sunken jewels and in order to do so, he/she has to follow them on the screen when a bubble or fish hides them.

2. Road Tour™ - In this computer simulation, the participant takes a trip along Route 66, locating road signs and identifying other cars along the way and expanding useful field of view as well as processing speed.

The purpose of the DriveSharp™ program is to help individuals improve UFOV, which correlates to visual attention (K. Ball, et al., 2002). It does so by continually adapting to the individual's performance during the exercises, so that the training is always at the appropriate level for the individual (Zelinski, Yaffe, Ruff, Kennison, & Smith, 2007). Participants were required to engage in training at its recommended dosage by Posit's scientific team (60 min/day, 5 days/week, 2 weeks). They were encouraged to engage in training twice a day for 30-minute sessions, once in the morning and once in the afternoon so as to reduce fatigue.

2.4 Procedures

2.4.1 Screening. All participants completed a number of screening steps to determine eligibility (see Appendix A). For safety of the participants and other drivers, exclusion criteria included neurological or psychiatric difficulties, a driver's license issued less than 4 years ago, infrequent driving (less than 3 times per week), poor overall health, hospitalization within the last 6 months, and being a driver in a police-reported accident in the last year. In addition, due to interference that would occur with the eye-tracking cameras, participants were excluded if they needed glasses to drive (contact lenses were acceptable). The greater study involved the collection of physiological measurements and thus participants were excluded if they had a pacemaker or were taking the following medications within the last year: anticonvulsant, immunosuppressant/ cytotoxic, antidepressant, anxiolytic, antipsychotic medications or

ones to treat a major medical illness such as cancer or cause drowsiness in order to ensure driver safety. Prior to participation, participants were screened to determine whether they could commit to the time and computer requirements necessary for the training. After the individual was deemed eligible and agreed to move forward, he/she was scheduled for the first visit.

The Institutional Review Boards at the University of Massachusetts – Boston (UMB) and the Massachusetts Institute of Technology (MIT), approved this study. During the first visit, potential participants met with a research assistant who provided detailed information about the study, obtained informed consent, and reviewed inclusion and exclusion criteria. Once consented, participants were assessed with the Mini Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975), which provides a gross screening measure of cognition that is often used in studies of aging and dementia and has shown to have a moderately high correlation (0.52 – 0.72) with road scores (Odenheimer, Beaudet, Jette, & Albert, 1994). Only participants with scores of 26 or higher out of a maximum of 30, which is the cut-off for normal cognitive functioning (Scott, M.D., & Caine, 2002), were allowed to continue to the Repeatable Battery for Assessment of Neuropsychological Status (RBANS; Randolph, 1998). The RBANS is individually administered test measuring attention, language, visuospatial constructional abilities, and immediate and delayed memory. It consists of 12 subtests, which yield five index scores and a total scaled score. Normative information from the manual for these scores is based on 540 healthy adults who ranged in age from 20–89 years old. To continue with the training and the on-road assessment, individuals needed to obtain an

RBANS Total Scale scores representative of normal aging (taken to be 2 standard deviations within the normative population range, 70-130).

2.4.2 Randomization. After all registered participants were scheduled they were randomly assigned to either the intervention group (DriveSharp™) or a waitlist control group using a fixed randomization scheme with assignment alternating between intervention and waitlist control. See Appendix B for chart.

2.4.3 Neuropsychological Assessment. All participants were given identical neuropsychological assessments. During every visit (Visit 1, 2 and 3), participants were administered the UFOV test (K. K. Ball, et al., 1988) and ANT (Fan, et al., 2002). Trailmaking (Franzen, et al., 1996; Reitan, 1986) was administered at visits 1 and 2 for the immediate intervention group and at visits 2 and 3 for waitlist controls. Trailmaking A/B was counterbalanced with C/D. The assessments in the neuropsychological battery are different from the training exercises, ensuring that any changes seen in the performance on the assessment would represent true generalization of improvement rather than to familiarization to visually similar tasks. Appropriate measures were taken to minimize practice effects, which are a concern for neuropsychological tests, particularly ones with a speeded component and those requiring an infrequently practiced response, or those having a single easily conceptualized solutions (Lezak, 1995).

<u>Trailmaking (Franzen, et al., 1996; Reitan, 1986).</u> This is a neuropsychological test of visual attention and cognitive flexibility. The task requires that participants connect-the-dots of 25 consecutive targets on a sheet of paper. The goal is for the participant to finish the test as quickly as possible without making mistakes. The primary measure is time for completion in seconds, which was also converted to standardized

scores. Trailmaking A and C are a test of focused attention related to visual scanning and processing speed, whereas Trailmaking B and D are related to divided attention involving inhibiting a dominant response while maintaining set. Due to the nature of practice effects in this measure (Fals-Stewar, 1992), which is common in psychomotor tests (Spikman, Timmerman, van Zomeren, & Deelman, 1999), Trailmaking C and D were used and parallel the original (Franzen, et al., 1996).

Trailmaking A has shown moderate correlations with various driving outcome measures (Fox, Bowden, Bashford, & Smith, 1997; B. L. Mazer, et al., 1998); and, Trailmaking B has shown moderate correlation with both physician's predictions of performance on a road test (r=0.410; Fox, et al., 1997) and the Behind-the-Wheel Evaluation (BTWE) Street Index (Galski, Bruno, & Ehhle, 1992).

Useful Field of View (UFOV) test (K. K. Ball, et al., 1988). The UFOV test measures the speed at which one can rapidly process multiple stimuli across the visual field; however, the participant can to take his or her time in responding. UFOV is not a reaction time test; but rather focuses on the accuracy of responses. UFOV does not correlate with visual acuity but rather is a measure of attentional resources and their spatial distribution (K. K. Ball, et al., 1988). Of note, the test-retest reliability is moderately high (r = 0.884; Edwards, Vance, et al., 2005). The test, which is administered on a personal computer, requires an individual to identify targets presented at varying durations, ranging from 16.67 to 500 ms. For each of the three subtests, the test will automatically adjust the length of stimulus presentation in milliseconds as needed. After two correct responses, stimulus presentation time for the next item will be shortened, whereas stimulus presentation time for the next item will be lengthened if the

a response was is incorrect. This process of tracking the perceptual threshold is continued until a stable estimate of 75% correct is calculated and ultimately results in the dependent measure of the UFOV test and may be as short as 14 presentations or much longer. The length of time necessary to obtain the stable measure will depend upon the consistency of the participant's responses.

Three subtests were administered (processing speed, divided attention, and selective attention). Each trial consists of four display screens: 1) a fixation box, 2) a test stimulus, 3) a full-field, white noise visual mask, and 4) a response screen. The white-noise visual mask is presented following the stimuli in order to control display duration and to eliminate afterimages. For each subtests, the target, which is either a silhouette of a 2 cm by 1.5 cm truck or car, is presented on a black background in a 3 cm × 3 cm fixation box. The first subtest, which measures processing speed under the lowest demand conditions, requires participants to identify a target presented at a central fixation point on the screen. The second subtest, which measures processing speed for a divided attention task, involves identification of this central target along with localization of a simultaneous peripheral target, which is a 2 cm x 1.5 cm silhouette of a car, and is presented at one of 8 radial locations. The third subtest, which measures processing speed for a selective attention task, includes these two tasks, but also includes visual distracters (e.g., triangles of the same size and luminance as the targets) arranged in concentric circles around the peripheral target (Edwards et al., 2005; Vance et al., 2007). Appendix C displays the screens and stimuli for the UFOV test. Scores for each subtest can range from 16.67 to 500 ms, which denotes the stimuli presentation time during with the participant is accurately responding.

First, the UFOV test and assessment have been used extensively to investigate the effects of cognitive training on performance (K. Ball, et al., 2002; Edwards, Delahunt, & Mahncke, 2009; B. L. Mazer, et al., 2003; Roenker, Cissell, Ball, Wadley, & Edwards, 2003). One study reported improvements on all 3 UFOV subtests after 20-session training (Mazer, Sofer, Korner-Bitensky, & Gelinas, 2001). It also has been found to relate to on-road driving ability across age groups (Clay, et al., 2005; Myers, Ball, Kalina, Roth, & Goode, 2000) and has expanded to include special populations such as those with neurological changes like a traumatic brain injury (Novack, et al., 2006), multiple sclerosis (Schultheis, Garay, & DeLuca, 2001), and stroke (B. L. Mazer, et al., 1998). For example, in a retrospective study of individuals with stroke, the correlation between UFOV and on-road driving ability was moderate ($r = 0.43$), but not in a prospective study (Akinwuntan, et al., 2006). In addition, UFOV is correlated with accidents ($r = 0.32$) and road test performance ($r = -0.66$; De Raedt & Ponjaert-Kristoffersen, 2001). Research has shown that the specificity in crash prediction is 81-84.2% and its sensitivity is 86.3-89% at the standard cut off score of 40% reduction in UFOV (K. Ball & Owsley, 1993; Goode, et al., 1998).

<u>Attention Network Test (ANT; Fan, et al., 2002) – short version.</u> The ANT is administered on a computer and gives measures of different aspects of the complex process of attention (alerting, orienting, and conflict; (Fan, et al., 2002)). Due to the administration of the short version and its limited number of stimuli, only the measure of conflict is valid (Fan, 2009). The conflict (executive control) involves mechanisms for monitoring and resolving conflict responses.

Stimuli consisted of a row of five visually presented horizontal black lines, with arrowheads pointing leftward or rightward against a gray background. The central target, a leftward or rightward arrowhead, was flanked by two arrows on each side, these four target flankers all pointed either in the same direction as the central target (congruent condition) or in the opposite direction as the central target (incongruent condition). For the neutral condition, horizontal lines instead of arrows flanked the central target, two horizontal lines on each side of the target. Subjects responded to the direction of the centrally presented target by pressing one key for the left direction and a different key for the right direction. A single arrow or line consisted of .55 degree of visual angle and the contours of adjacent arrows or lines were separated by 0.06 degree of visual angle. The stimuli (one central arrow plus 2 left flankers, 2 right flankers) consisted of a total 3.8-degree visual angle.

Subjects first fixated on a central cross of random variable duration (400-1600 ms), and then a warning cue for 100 ms. Following a short fixation period of 400 ms after the warning cue, the target and flankers appeared simultaneously. The target and flankers remained on until a response was made, but for no longer than 1700 ms, followed by an inter-trial interval of variable duration based on the duration of the first fixation and reaction time (RT; 3500 ms minus duration of first fixation minus RT). After this interval, the next trial began. Each trial lasted 4000 milliseconds. The fixation-cross appeared at the center of the screen during the whole trial. The row of five stimuli, presented either 1.06 degree above or below the fixation point, was preceded be one of four different warning conditions: no cue, center cue, double cue, and spatial cue. For the

no-cue trials, subjects saw only a fixation cross for 100 ms. For the center-cue trials, subjects saw an asterisk at the location of fixation cross for 100 ms. For the double-cue trials, subjects saw two warning cues corresponding to the two possible target positions-up and down. For the spatial cue trials, the cue, always valid, appeared at the exact location of the subsequent target.

The conflict RT was calculated by subtracting the mean reaction time (RT) of all congruent flanking conditions, summed across cue types, from the mean RT of incongruent flanking conditions. Appendix D gives examples of the conditions and stimuli as they are presented in the program. All combinations of conditions are randomly presented in three blocks of 48 trials each. The dependent measures are the median reaction times for conflict, errors committed, and the average reaction time across conditions.

2.4.4 Intervention Compliance Assessment. The intervention compliance was verified through Posit records. The average number of total minutes spent on training was 479.94 (*SD* = 126.10), on Jewel Driver it was 234.44 (*SD* = 79.80), and Road Tour was 296.87 (*SD* = 109.72). While this is less than the goal of 600 minutes, developers of DriveSharp™ cited improvement with a minimum of 480 minutes.

2.4.5 Driving Assessment.

Apparatus. The driving assessment comprised of an on-road assessment in the M.I.T. Aware Car, an instrumented vehicle (Lincoln MKS 2010, see Appendix E), that is equipped with a customized data acquisition system designed for time synchronized measurement of vehicle, driver and environmental factors. Data capture was facilitated through a number of embedded sensing systems including: vehicle telemetry (CAN bus

link), eye tracking and video recordings. In addition to capturing data, the system included functionality for manual and time based triggering that was used for the presentation of secondary tasks. Participants' driving performance, cognitive tasks performance and the environment in which the vehicle was being operated were recorded through the following: vehicle sensors, physiological measures in data files, video and audio recordings. Eye-tracking data were logged at up to 60 Hz by using a Seeing Machines FaceLAB 5 eye-tracking system.

Route. The route consisted of highway driving. The participant spent about 30 minutes traveling north on Interstate 93 and then turned around at Exit 37B (I-95) to return back to Cambridge. During the northbound trip, participants completed the visual working memory secondary task, and during the southbound trip, they completed the auditory working memory secondary task.

Secondary Tasks. Attention can be conceptualized as a limited resource (Parasuraman & Nestor, 1991). According to this model, attention is represented as a central bank of resources, which is available for tasks that require mental effort. The amount of available resources can vary with arousal level as well (Kahneman, 1973; Kahneman, Ben-Ishai, & Lotan, 1973). However, the attentional capacity reflects the demands made at the perceptual level (e.g., driving), the level at which the input information is interpreted, and the response selection stage (Posner & Boies, 1971). Participants completed two working memory tasks that were not counterbalanced. In this experiment, individuals completed secondary tasks while driving that could be used to place demands on the driver without requiring direct conflict with the manual control or visual processing demands of the primary driving task (Mehler, Reimer, Coughlin, &

Dusek, 2009). This procedure has shown to be a valid measure of divided attention during driving (Mehler, et al., 2010; Mehler, et al., 2009; Reimer & Mehler, in press; Reimer, et al., 2009; Schieber & Gilland, 2005, 2008; Schieber & Schlorholtz, 2006). The primary dependent measure is eye-gaze during driving while performing this task. The secondary measure is accuracy on the task.

An auditory prompt / verbal response "n-back" task was selected as a secondary task and it was expected that the 1-back would have moderate impact on individuals given previous studies (Reimer, et al., 2010) and provide a secondary probe of the attentional demands of the concurrent task of driving the car. Prior to the drive, written instructions were provided on how to complete the 1-back task. Participants were asked to read along as a research associate read the instructions aloud. Additional repetitions of the instructions and practice trails of each task were presented until participants demonstrated a minimum proficiency of 7 correct responses. The form of the 1-back employed consisted of a series of 10 single digit numbers [0 – 9] presented aurally to the subject. Each value was presented once per test set and the order of the digits varied with each presentation. The 10 numbers were presented with an inter-stimulus interval of 2.25 seconds, thus requiring fairly rapid response from the subject to keep pace with the task. Consecutive tests appeared every 30 seconds, allowing for only a brief pause between sets. Each task level consisted of 4 test sets for a total testing period of 2 minutes per level. All instructions and tasks were pre-recorded and played automatically during the protocol. In the "1-back" condition, the subject was required to recall from memory and respond aloud with the number that was presented just prior to the current number (i.e., 1 back from the current number). This represents an additional step up in divided attention

in that the individual must both correctly recall from short-term memory the item presented previously as well as entering and holding the new item in memory.

The second task was a visual working memory task called the Clock task, which has been used in previous driving research studies (Schieber & Gilland, 2008; Schlorholtz & Schrieber, 2006). During this task, the participant is asked to visualize the location of a specified time's hour and minute hands as they are seen on the face of an imaginary analog clock. They then ask themselves the following yes/no questions, "Is the angle formed by the hour and minute hands less than 90 degrees?" Prior to the drive, written instructions were provided on how to complete the clock task. Participants were asked to read along as a research associate read the instructions aloud. Additional repetitions of the instructions and practice trails of each task were presented until participants demonstrated a minimum proficiency of 7 correct responses. Participants were administered 12 trials over 2 minutes. All instructions and tasks were pre-recorded and played automatically during the protocol.

2.5 Data Analysis

Gaze measures were computed directly from the eye trackers' world coordinate system by using a methodology analogous to that of previous studies at the MIT AgeLab (Reimer, 2009; Reimer, et al., 2010; Sodhi, et al., 2002). A valid measurement is defined as a gaze within a set of six valid measurements (approximately 100 ms). Summary statistics were only completed for participants for whom more than half of the potential data points were valid. Comparisons of central location and dispersion were computed based upon the mean position and standard deviation of positions, respectively. FaceLAB

extracted the vertical and horizontal components of the gaze vector from the global coordinate system.

Data were analyzed using PASW v. 18. Chi-squared and t-tests (two-tailed) analyses first examined comparability of groups on baseline demographic and neuropsychological measures for waitlist control and DriveSharp™ participants. Initial analyses sought to determine whether the training led to improvements on 1) neuropsychological measures and b) eye gaze during driving. To evaluate the effects of DriveSharp™ training paired-sample t-tests were used to test the hypothesis that 10 hours of sessions of DriveSharp™ would show significant improvement in neuropsychological measures of attention (except for Trailmaking) and eye gaze behavior while driving. The dependent variables were the neuropsychological and eye gaze measures. The independent variable was visit (i.e., baseline or post-intervention). This was done for DriveSharp™ only comparing visits 1 and 2, waitlist control after receiving intervention comparing visits 1 and 3, and combined group comparing visits 1 and visits 2 or 3.

To evaluate the changes in scores across multiple visits for the waitlist control groups a within group repeated measures Analysis of Variance (ANOVA; visits 1, 2, and 3) was conducted for neuropsychological and eye gaze measures. In addition, a mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (pre-test, post-test) was conducted. Of note, all analyses were repeated using those who had completed the minimum 480 minutes of training. Results include effect sizes to allow direct comparison of different outcome. A *p*-value of less than or equal to 0.05 was considered significant.

CHAPTER 3

RESULTS

3.1 Baseline Comparisons

Table 1 presents baseline comparisons of immediate DriveSharp™ training and waitlist control participants on demographic characteristics. As shown, the training and waitlist groups did not differ in gender, age, and race. Both groups showed similar cognitive profiles on the RBANS for total score as well as across test indices (immediate and delayed memory, visuospatial, language, and attention). In addition, participants who completed the minimum 480 minutes of training (n = 17) did not differ from those who completed less than the minimum eight hours of training (n = 15) on demographic variables (age, gender, race, education, and handedness). However, participants who completed the minimum eight hours of training scored higher scores on the delayed memory index of the RBANS, $F(1,30) = 2.19$, $p = 0.04$.

3.2 Cognitive Performance

3.2.1 Comparisons of performance on the Trailmaking test at baseline and after training with DriveSharp™. Participants were evaluated with three main tests of attention. Table 2 presents a neuropsychological summary of time to completion scores and z-scores for the Trailmaking test.

<u>Trailmaking A/C.</u> For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores

on the Trailmaking A/C (see Figure 3). There was a statistically significant decrease in the time to completion on Trailmaking A/C from baseline (M = 36.35 seconds, SD = 13.95) to post-intervention (32.19 seconds, SD = 10.20), $t(31) = 2.08$, $p < 0.05$, $d = 0.12$. The raw data was also converted to z-scores against a normed population. Having done so, there was a significant improvement in z-scores on Trailmaking A/C from baseline (M = 0.16, SD = 1.00) to post-intervention (M = 0.45, SD = 0.84), $t(31) = -2.09$, $p < 0.05$, d = 0.12. These results did not retain significance when it was reduced to only participants who completed the minimum 480 minutes of training (n = 17). However, effect sizes showed moderate effect sizes following intervention for both time to completion, $t(16)$ = 1.38, $p = 0.19$, $d = 0.11$, and z-scores, $t(16) = -1.36$, $p = 0.19$, $d = 0.10$. When accounting for outliers, time to completion did not retain significance, $t(29) = 1.81$, $p = 0.08$, however, there was a moderate effect size, $d = 0.11$. There was a significant improvement in z-scores from baseline (M = 0.36, SD = 0.64) to post-intervention (M = 0.60, SD = 0.58), $t(28) = -2.80$, $p = 0.01$, $d = 0.21$.

Taken together, significant improvements were seen for both time to completion and z-scores. A similar pattern of effect sizes remained with those who engaged in the minimum 480 minutes of training and when outliers were removed.

Trailmaking B/D. For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the Trailmaking B/D (see Figure 3). There was no statistically significant difference in the time to completion after intervention, $t(31) = 0.12$, $p = 0.91$, $d < 0.01$. The raw data was also converted to z-scores against a normed population. Having done so, there was no statistically significant improvement in z-scores after intervention, $t(31) = -1.80$, p =

0.08; although there was a moderate effect size, *d* = 0.09. These results remained insignificant when the sample was reduced to those that completed the minimum 480 minutes of training (n = 17). Effect sizes showed large effect sizes after intervention for time to completion, $t(16) = 1.14$, $p = 0.27$, $d = 0.08$, and moderate effect sizes for z-scores, $t(16) = -1.11$, $p = 0.28$, $d = 0.07$. When accounting for outliers, neither time to completion, $t(29) = 1.25$, $p = 0.22$, $d = 0.05$, nor z-scores retained significance, $t(29) = -1.24$, $p = 0.22$, $d = 0.05$.

Taken together, while there were no significant differences in time to completion observed after intervention, there were moderate effect sizes for z-scores for the reduced sample of those who completed the minimum amount of training. When outliers were removed, results were not significant and effect sizes were small.

3.2.2 Comparisons of performance on UFOV. Participants were evaluated with three main tests of attention. Table 3 presents neuropsychological summary scores for the UFOV test.

Processing Speed. For the DriveSharp™ group, a paired-samples t-test was used to evaluate the impact of the intervention on UFOV processing speed (see Figure 4). There was no statistically significant difference in the reaction times after intervention, $t(15) = 1.44$, $p = 0.17$, notwithstanding a moderate effect size, $d = 0.12$. These results remained insignificant when it was reduced to only participants who completed the minimum 480 minutes of training (n = 10). Effect size was moderate for processing speed reaction time, $t(9) = 1.06$, $p = 0.32$, $d = 0.11$. Removing outliers from the sample did not reveal significant differences due to the lack of variability in the numbers.

For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), a paired-samples t-test was used to evaluate the impact of the intervention on participants' on UFOV processing speed (see Figure 4). There was no statistically significant difference in the reaction times after intervention, $t(15) = 1.73$, $p = 0.11$, although there was a large effect size, $d = 0.17$. These results remained insignificant when the sample was reduced to those that completed the minimum 480 minutes of training (n = 7). Effect size was large for processing speed reaction time, $t(6) = 1.00$, $p = 0.36$, $d = 0.14$. Removing outliers from the sample did not reveal significant differences due to the lack of variability in the numbers.

For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on UFOV processing speed (see Figure 4). There was a statistically significant decrease in the reaction times from baseline ($M = 27.41$ milliseconds, $SD = 29.10$) to post-intervention ($M = 17.01$ milliseconds, $SD = 1.77$), $t(31) = 2.06$, $p = 0.05$, $d = 0.12$. These results did not remain significant when the sample was reduced to those that completed the minimum 480 minutes of training (n = 17). However, there was a moderate effect size for processing speed reaction time, $t(16) = 1.41$, $p = 0.18$, $d = 0.11$. Removing outliers from the sample did not reveal significant differences due to the lack of variability in the numbers.

Due to the multi-visit design with the waitlist control group, analyses were performed to determine the degree of change between visits (see Table 5). Analyses between visits among the waitlist control group showed that there was no significant change in scores between visits, $F(1,15) = 2.99$, $p = 0.11$; although there was a large effect size, partial eta squared = 0.17. This same pattern held for those who completed the

minimum 480 minutes of training, $F(1,6) = 1.00$, $p = 0.36$, partial eta squared = 0.14. Of note, there was a significant amount of variance in the scores (see Figure 6).

Figure 8 presents the performance on UFOV processing speed reaction times between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was no significant interaction between groups and time, $F(1,30) = 0.33$, $p = 0.57$, partial eta squared = 0.01, but there was a main effect for time, $F(1,30) = 4.17$, $p = 0.05$, partial eta squared = 0.12, with both groups showing a reduction in UFOV Processing Speed over time and no between-subject group differences, $F(1,30) = 0.18$, $p = 0.67$, partial eta squared = 0.01. For the reduced sample of those completing the minimum 480 minutes of training, there was no significant different in main effect or between subjects. The sample excluding outliers did not reveal any significant changes due to the lack of variability in the data points.

Taken together, the only significant changes in processing speed reaction time occurred with the larger, combined group, however there were large effect sizes for the waitlist control group and moderate effect size for the DriveSharp™ group. Patterns generally remained insignificant but with large effect sizes when sample size was reduced. When looking at the multiple visits within the waitlist control group, there were no significant differences between visits but there were large effect sizes. In addition, when groups were compared (control vs. DriveSharp™), the presence of a time difference with no between subject differences might speak to practice effects.

Divided Attention. For the DriveSharp™ group, a paired-samples t-test was used to evaluate the impact of the intervention on UFOV divided attention (see Figure 4).

There was a statistically significant decrease in the reaction times from baseline (*M* = 113.57 milliseconds, *SD* = 106.78) to post-intervention (*M* = 31.26 milliseconds, *SD* = 30.93), *t*(15) = 3.61, *p* = 0.003, *d* = 0.46. This pattern of results held when the sample was reduced to only participants who completed the minimum 480 minutes of training (n = 10). There was a statistically significant decrease in the reaction times from baseline (*M* = 88.70 milliseconds, *SD* = 98.36) to post-intervention (*M* = 28.34 milliseconds, *SD* = 30.47), *t*(9) = 2.37, *p* = 0.04, *d* = 0.38. And again, when outliers were removed, there was a statistically significant decrease in reaction times from baseline (*M* = 83.34, *SD* = 90.45) and post-intervention (*M* = 16.70, *SD* = 0.00), *t*(11) = 2.55, *p* = 0.03, *d* = 0.37.

For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), a paired-samples t-test was used to evaluate the impact of the intervention on UFOV divided attention (see Figure 4). There was no statistically significant difference in the reaction times after intervention, *t*(15) = -0.33, *p* = 0.74, *d* = 0.01. These results remained insignificant when it was reduced to only participants who completed the minimum 480 minutes of training (n = 7), *t*(6) = -0.23, *p* = 0.83, *d* = 0.01. However, when outliers were removed, there was a large effect size, *t*(11) = 1.82, *p* = 0.09, *d* = 0.22.

For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the divided attention (see Figure 4). There was no statistically significant difference in the reaction times after intervention, *t*(31) = 1.94, *p* = 0.06, although there was a moderate effect size, *d* = 0.11. These results remained insignificant when the sample was reduced to those that completed the minimum 480 minutes of training (n = 17). However, there were large

effect sizes for divided attention reaction time, $t(16) = 1.00$, $p = 0.08$, $d = 0.18$. When outliers were removed, there as significant decrease from baseline ($M = 108.88$, $SD = 53.20$) to post-intervention ($M = 72.92$, $SD = 38.19$), $t(30) = 5.50$, $p < 0.001$, $d = 0.26$.

Analyses between visits among the waitlist control group (see Table 5) showed that there was a significant change in scores between visits, $F(2, 14) = 3.73$, $p = 0.05$, partial eta squared = 0.35. However, this same pattern did not hold for those who completed the minimum 480 minutes of training despite the medium effect size, $F(2,5) = 1.31$, $p = 0.35$; although there was a large effect size, partial eta squared = 0.34. There were only significant differences between visits 1 and 3, $p = 0.02$. Of note, there was a significant amount of variance in the scores (see Figure 6). When outliers were removed, there were no significant differences between visits despite a large effect size, $F(2,9) = 2.14$, $p = 0.17$, partial eta squared = 0.32.

Figure 8 presents the performance on UFOV divided attention reaction times between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was a significant interaction between groups and time, $F(1,30) = 6.87$, $p = 0.01$, partial eta squared = 0.19, given the high initial value of the DriveSharp™ group's visit 1 reaction time score. Of note, there was a statistically significant difference between groups on visit 1 ($p = 0.03$) with the intervention group being significantly higher than the control group. In addition, there was a main effect for time, $F(1,30) = 4.48$, $p = 0.04$, partial eta squared = 0.13, with both groups showing a reduction in UFOV divided attention over time. However, there was no between group effect, $F(1,30) = 1.02$, $p = 0.32$, partial eta squared = 0.03. For those who completed the

minimum 480 minutes of training, there was no significance as well. When outliers were removed, there was a significant interaction, $F(1,22) = 4.72$, $p = 0.04$, partial eta squared = 0.17. There was both a main effect for time, $F(1,22) = 7.95$, $p = 0.01$, partial eta squared = 0.27, and also significant between group differences, $F(1,30) = 4.27$, $p = 0.05$, partial eta squared = 0.16.

Taken together, significant reductions in reaction times were observed for the DriveSharp™ across groupings and also for the combined group when outliers were removed. Examination of the waitlist control group over 3 visits determined differences in reaction times across visits, of which the significance between visits 1 and 3 might point to changes from intervention and not practice effects. In addition, when groups were compared (control vs. DriveSharp™), when outliers were removed there was a significant difference between subjects; however, for the remaining groups, there were no significant differences between groups.

Selective Attention. For the DriveSharp™ group, a paired-samples t-test was used to evaluate the impact of the intervention on UFOV selective attention (see Figure 4). There was a statistically significant decrease in the reaction times from baseline (M = 132.13 milliseconds, $SD = 67.64$) to post-intervention (M = 82.93 milliseconds, SD = 46.69), $t(15) = 4.38$, $p = 0.001$, $d = 0.56$. This pattern of results held when the sample was reduced to those that completed the minimum 480 minutes of training (n = 10). There was a statistically significant decrease in the reaction times from baseline (M = 111.39 milliseconds, $SD = 55.12$) to post-intervention (M = 69.69 milliseconds, $SD = 43.52$), $t(9) = 3.54$, $p = 0.006$, $d = 0.58$. And again, when outliers were removed, there remained a statistically significant decrease in the reaction times from baseline (M = 57.53

milliseconds, *SD* = 14.85) to post-intervention (*M* = 46.27 milliseconds, *SD* = 11.95), *t*(14) = 4.31, *p* = 0.001, *d* = 0.57.

For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the divided attention (see Figure 4). There was no statistically significant difference in the reaction times after intervention, *t*(15) = -0.47, *p* = 0.65, *d* = 0.01. This effect remained not significant when the sample was reduced to those who completed the minimum 480 minutes of training (n = 7), *t*(6) = -1.02, *p* = 0.35, although there was a large effect size, *d* = 0.15. There was, however, a significant decrease in reaction time when outliers were removed, *t*(15) = 3.45, *p* = 0.004, *d* = 0.44. Reaction time at baseline (*M* = 96.11, *SD* = 47.03) decreased to post-intervention (*M* = 28.86, *SD* = 7.21).

For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the divided attention (see Figure 4). There was no statistically significant difference in the reaction times after intervention, *t*(31) = 1.32, *p* = 0.20, *d* = 0.05. However, when the sample was reduced to only participants who completed the minimum 480 minutes of training (n = 17), there was a significant effect of intervention, *t*(16) = 3.25, *p* = 0.01, *d* = 0.41. Reaction times after intervention (*M* = 73.55 milliseconds, *SD* = 38.21) decreased from baseline (*M* = 104.56 milliseconds, *SD* = 46.14). When outliers were removed, there remained a significant difference after intervention, *t*(30) = 3.25, *p* < 0.01, *d* = 0.50. Reaction times after intervention (*M* = 38.19 milliseconds, *SD* = 6.86) decreased from baseline (*M* = 53.20 milliseconds, *SD* = 9.55).

Analyses between visits among the waitlist control group (see Table 5) showed that there was a significant change in scores between visits, $F(2, 14) = 3.73$, $p = 0.02$, partial eta squared = 0.45, with significant differences occurring between visits 1 and 3 ($p = 0.004$). However, this same pattern did not hold true for those who completed the minimum 480 minutes of training, $F(2,5) = 5.21$, $p = 0.06$; although there was a large effect size, partial eta squared = 0.68. However, with regard to the former, there were only significant differences between visits 1 and 3, $p = 0.004$. Of note, there was a significant amount of variance in the scores, particularly for visit 2 (see Figure 6). When outliers were removed, there was a significant difference across visits, $F(2,13) = 6.35$, $p = 0.01$, partial eta squared = 0.49. There were significant differences between visits 1 and 3 ($p = 0.01$) and 2 and 3 ($p = 0.02$).

Figure 8 presents the performance on UFOV selective attention reaction times between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was a significant interaction between group and time, $F(1,30) = 5.09$, $p = 0.03$, partial eta squared = 0.15. There was no main effect for time, $F(1,30) = 1.98$, $p = 0.17$, partial eta squared = 0.06, or between-subject differences, $F(1,30) = 0.07$, $p = 0.80$, partial eta squared = 0.002. For those who completed the minimum 480 minutes of training, there was no interaction, $F(1,15) = 2.32$, $p = 0.15$, with a moderate effect size, partial eta squared = 0.13 but a significant difference for time, $F(1,15)= 9.38$, $p = 0.01$, with a large effect size, partial eta squared = 0.39; however, there were no between subject differences, $F(1,15) = 0.02$, $p = 0.90$, partial eta squared = 0.001. When outliers were removed, there was a significant interaction,

$F(1,28) = 6.35$, $p = 0.03$, partial eta squared = 0.16, as well as main effect for time, $F(1,28) = 15.79$, $p < 0.001$, partial eta squared = 0.36. There were no significant differences between groups.

Taken together, improvement in reaction times was observed for the DriveSharp™ group. When the sample was reduced, the waitlist control group had a large effect size and the combined group showed a significant reduction in reaction time. When outliers were removed, across groups, there were significant reductions. Examination of the waitlist control group over 3 visits determined differences in reaction times across visits, of which the significance between visits 1 and 3 might point to changes from intervention and not practice effects. In addition, when groups were compared (control vs. DriveSharp™), the presence of a time difference with no between subject differences might speak to practice effects. However, this was only present in the reduced sample and when outliers were removed.

3.2.3 Comparisons of performance on the ANT. Participants were evaluated with three main tests of attention. Table 4 presents neuropsychological summary scores for the ANT test.

Conflict Reaction Time. For the DriveSharp™ group, a paired-samples t-test was used to evaluate the impact of the intervention on the conflict reaction time (milliseconds) for the ANT (see Figure 5). There was a statistically significant decrease in the reaction times after intervention ($M = 99.10$ milliseconds, $SD = 43.47$) from baseline ($M = 128.88$ milliseconds, $SD = 55.45$), $t(15) = 3.14$, $p = 0.01$, $d = 0.40$. This pattern of results held when the sample was reduced to those participants who completed the minimum 480 minutes of training (n = 10). There was a statistically significant

decrease in the reaction times after intervention (*M* = 93.16 milliseconds, *SD* = 45.84) from baseline (*M* = 121.58 milliseconds, *SD* = 56.25), $t(9) = 2.38$, $p = 0.04$, $d = 0.39$. Again, this pattern remained when outliers were removed, $t(15) = 3.14$, $p = 0.01$, $d = 0.40$, where there was a statistically significant decrease in reaction times after intervention (*M* = 43.48 milliseconds, *SD* = 10.89) from baseline (*M* = 55.45 milliseconds, *SD* = 13.86).

For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), a paired-samples t-test was used to evaluate the impact of the intervention on the conflict reaction time (milliseconds) for the ANT (see Figure 5). There was no statistically significant difference in the reaction times after intervention, $t(15) = 1.63$, $p = 0.12$, although there was a large effect size, $d = 0.15$. This effect still did not reach significance when the sample was reduced to those who completed the minimum 480 minutes of training (n = 7), $t(6) = -1.13$, $p = 0.30$; but again there was a large effect size, $d = 0.17$. However, when outliers were removed, there was a significant decrease in reaction time from baseline (*M* = 50.03, *SD* = 12.92) to post-intervention (*M* = 28.50, *SD* = 7.36), $t(14) = 2.73$, $p = 0.02$, $d = 0.35$.

For the total sample that received the training, a paired-samples t-test was used to evaluate to evaluate the impact of the intervention on the conflict reaction time (milliseconds) for the ANT (see Figure 5). There was a statistically significant decrease in the reaction times after intervention (*M* = 100.42 milliseconds, *SD* = 37.61) from baseline (*M* = 132.90 milliseconds, *SD* = 64.65), $t(31) = 2.80$, $p = 0.01$, $d = 0.20$. While the effects did not remain significant when the sample was reduced to those participants who completed the minimum 480 minutes of training (n = 16), $t(16) = 1.90$, $p = 0.07$,

there was a large effect size, *d* = 0.19. However, when outliers were removed, there was a significant decrease in reaction time from baseline ($M = 52.11$, $SD = 9.36$) to post-intervention ($M = 36.56$, $SD = 6.57$), $t(30) = 4.20$, $p < 0.001$, $d = 0.35$.

Analyses between visits among the waitlist control group (see Table 5) showed that there was a significant change in scores between visits for the total sample, $F(2, 14) = 3.95$, $p = 0.04$, partial eta squared = 0.36. There was a significant difference between visits 1 and 3 ($p = 0.03$). However, this same pattern did not hold true for those who completed the minimum 480 minutes of training, $F(2,5) = 2.16$, $p = 0.21$; although there was a large effect size, partial eta squared = 0.46 (see Figure 7). When outliers were removed, there were no significant differences across visits $F(2, 13) = 3.56$, $p = 0.06$, although there was a large effect size, partial eta squared = 0.36. There were significant differences between visits 1 and 3 ($p = 0.02$).

Figure 9 presents the performance on ANT conflict reaction times between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was no significant interaction between groups and time, $F(1,30) = 0.05$, $p = 0.82$, partial eta squared = 0.002. There was a main effect for time, $F(1,30) = 7.58$, $p = 0.01$, partial eta squared = 0.20, with both groups showing a reduction in ANT conflict reaction time over time. There were no differences between groups, $F(1,30) = 0.13$, $p = 0.72$, partial eta squared = 0.004, suggesting no difference in effectiveness of the intervention. For those who completed the minimum 480 minutes of training, there were no significant differences. When outliers were removed, there was no interaction, $F(1,29) = 0.96$, $p = 0.34$, partial eta squared = 0.03, but there was a main effect for time,

F(1,29) = 10.44, *p* = 0.003, partial eta squared = 0.27. No between group differences were found, *F*(1,29) = 0.003, *p* = 0.95, partial eta squared < 0.001.

Taken together, significant improvement in reaction times was observed for the DriveSharp™ group and for the remaining groups when outliers were removed. The remaining groups had large effect sizes. Examination of the waitlist control group over 3 visits determined differences in reaction times across visits, of which the significance between visits 1 and 3 might point to changes from intervention and not practice effects. In addition, when groups were compared (control vs. DriveSharp™), the presence of a time difference with no between subject differences might speak to practice effects.

Average Reaction Time. For the DriveSharp™ group, a paired-samples t-test was used to evaluate to evaluate the impact of the intervention on the average reaction time (milliseconds) for the ANT (see Figure 5). There was a statistically significant decrease in the reaction times after intervention (*M* = 676.48 milliseconds, *SD* = 91.75) from baseline (*M* = 725.82 milliseconds, *SD* = 95.93), *t*(15) = 4.09, *p* = 0.001, *d* = 0.52. This pattern of results held when the sample was reduced to those participants who completed the minimum 480 minutes of training (n = 10). There was a statistically significant decrease in the reaction times after intervention (*M* = 648.77 milliseconds, *SD* = 74.16) from baseline (*M* = 705.77 milliseconds, *SD* = 87.84), *t*(9) = 3.25, *p* = 0.01, *d* = 0.54. This same pattern remained when outliers were removed. There was a statistically significant decrease in the reaction times after intervention (*M* = 713.18 milliseconds, *SD* = 76.37) from baseline (*M* = 659.37 milliseconds, *SD* = 63.26), *t*(14) = 4.00, *p* = 0.001, *d* = 0.53.

For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), a paired-samples t-test was used to evaluate the impact of the intervention on the average reaction time (milliseconds) for the ANT (see Figure 5). There was a statistically significant decrease in the reaction times from baseline (M = 723.36 milliseconds, SD = 115.92) to post-intervention (M = 694.13 milliseconds, SD = 108.05), $t(15) = 3.26$, $p = 0.01$, $d = 0.42$. This same pattern remained when outliers were removed. There was a statistically significant decrease in the reaction times after intervention (M = 723.36 milliseconds, SD = 115.93) from baseline (M = 672.06 milliseconds, SD = 103.16), $t(15) = 3.40$, $p = 0.004$, $d = 0.44$.This effect was no longer significant when the sample was reduced to those participants who completed the minimum 480 minutes of training (n = 7), $t(6) = 1.75$, $p = 0.13$; however, there was a large effect size, $d = 0.34$.

For the total sample that received the training, a paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the average reaction time (milliseconds) for the ANT (see Figure 5). There was a statistically significant decrease in the reaction times from baseline (M = 725.94 milliseconds, SD = 104.70) to after intervention (M = 685.30 milliseconds, SD = 99.01), $t(31) = 5.13$, $p < 0.001$, d = 0.46. This pattern of results held when the sample was reduced to those participants who completed the minimum 480 minutes of training (n = 17). There was a statistically significant decrease in the reaction times from baseline (M = 704.75 milliseconds, SD = 107.80) to after intervention (M = 661.05 milliseconds, SD = 96.10), $t(16) = 3.59$, p = 0.002, $d = 0.45$. This same pattern remained when outliers were removed. There was a statistically significant decrease in the reaction times after intervention (M = 665.92

milliseconds, $SD = 85.03$) from baseline ($M = 718.44$ milliseconds, $SD = 97.30$), $t(30) = 5.26$, $p < 0.001$, $d = 0.48$.

Analyses between visits among the waitlist control group (see Table 5) showed that there was a significant change in scores between visits for the total sample, $F(2, 14) = 7.48$, $p = 0.006$, partial eta squared = 0.52, as well as when outliers were removed, $F(2, 14) = 7.48$, $p = 0.006$, partial eta squared = 0.52. For both, there were significant differences between visits 1 and 2 ($p = 0.01$ for both) as well as between visits 2 and 3 ($p = 0.004$ for both). However, this same pattern did not hold true for those completed the minimum 480 minutes of training, $F(2,5) = 1.39$, $p = 0.33$, partial eta squared = 0.36. However, with regard to the former, there were significant differences between visits 1 and 2 ($p = 0.005$) as well as between visits 1 and 3 ($p = 0.004$). However, the same comparisons were not evident in those that completed the minimum 480 minutes of training. Figure 7 depicts the change among visits.

Figure 9 presents the performance on ANT average reaction times between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was no significant interaction between groups and time, $F(1,30) = 2.15$, $p = 0.15$, partial eta squared = 0.07. There was a main effect for time, $F(1,30) = 27.29$, $p < 0.01$, partial eta squared = 0.48, with both groups showing a reduction in ANT average reaction time over time. There were no differences between groups, $F(1,30) = 0.03$, $p = 0.80$, partial eta squared = 0.001. For those that completed the minimum 480 minutes of training, there was no significant interaction between groups and time, $F(1,15) = 1.79$, $p = 0.20$, partial eta squared = 0.11. There was a main effect for

time, $F(1,15) = 11.42$, $p = 0.004$, partial eta squared = 0.43, with both groups showing a reduction in ANT reaction time over visits one and two. There were no differences between groups, suggesting no difference in effectiveness of the intervention, $F(1,15) = 0.07$, $p = 0.79$, partial eta squared = 0.01. This same pattern remained when outliers were removed with an insignificant interaction, with a significant difference for time, $F(1,29) = 27.02$, $p < 0.001$, partial eta squared = 0.48 with no between group differences.

Taken together, significant improvements in reaction times were observed for all the DriveSharp™ and combined groups in the total sample and when outliers were removed. When the sample was reduced to those that completed the minimum training, all groups showed large effect sizes, and the DriveSharp™. Examination of the waitlist control group over 3 visits determined differences in reaction times across visits, of which the significance between visits 1 and 3 and 2 and 3 cannot identify whether there were practice effects or changes from intervention. In addition, when groups were compared (control vs. DriveSharp™), the presence of a time difference with no between subject differences might speak to practice effects.

3.3 On-Road Performance

3.3.1 Comparisons of horizontal eye gaze during the auditory working memory task while driving. Participants' eye gaze was measured with standard deviation of horizontal eye gaze (Table 6). Eye gaze was measured at 3 time points: pre-task, during the task, and post-task (Figure 10). A repeated measure on the combined groups for Visit 1 was performed across these three time points of the task and showed a significant difference in horizontal eye gaze, $F(2,28) = 10.03$, $p = 0.001$, partial eta squared = 0.42. There were significant differences between pre-task and post-task when compared to

during the task, with $p < 0.001$ for both. This suggests that the cognitive task was restricting the eye-gaze and suggestive of divided attention. However, this same pattern did not hold for those that completed the minimum 480 minutes of training, as the changes were not significant, $F(2,13) = 1.77$, $p = 0.21$, partial eta squared = 0.21.

Pre-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of horizontal eye gaze (Figure 10). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention, $t(14) = 0.51$, $p = 0.62$, $d = 0.02$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = 0.51$, $p = 0.57$, $d = 0.04$. When outliers were removed, this pattern remained the same, $t(14) = 0.51$, $p = 0.62$, $d = 0.02$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention in the total sample, $t(13) = 0.36$, $p = 0.73$, $d = 0.01$, or when outliers were removed, $t(14) = 0.51$, $p = 0.62$, $d = 0.02$. This effect did not reach significance again when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 1.79$, $p = 0.13$; however, there was a large effect size, $d = 0.39$. There was no significant change in standard deviation in eye gaze after intervention for either the total sample that received the training, $t(28) = 0.62$, $p = 0.54$, $d = 0.01$, or the sample with outliers removed, $t(27) = 0.71$, $p = 0.48$, $d = 0.02$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(14) = 1.55$, $p = 0.14$; however, there was a large effect size, $d = 0.15$.

Figure 15 presents the standard deviation of horizontal eye gaze prior the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was no significant interaction between groups and time, $F(1,28) = 1.43$, $p = 0.24$, partial eta squared = 0.05, and there was no main effect for time, $F(1,28) = 0.19$, $p = 0.67$, partial eta squared = 0.01. There were differences between groups, $F(1,28) = 4.26$, $p = 0.05$, partial eta squared = 0.13. For those that completed the minimum 480 minutes of training, there was neither a significant interaction between groups and time, $F(1,13) = 1.12$, $p = 0.31$, partial eta squared = 0.08, nor a main effect for time, $F(1,13) = 0.12$, $p = 0.73$, partial eta squared = 0.01. There were still differences between groups, $F(1,13) = 6.50$, $p = 0.02$, partial eta squared = 0.33. Looking specifically at visit 1, there were significant changes between control ($M = 0.13$, $SD = 0.03$) and intervention groups ($M = 0.09$, $SD = 0.03$) at baseline ($p = 0.05$). When outliers were removed, there was no significance: no interaction, $F(1,26) = 1.41$, $p = 0.25$, partial eta squared = 0.05, no main effect for time, $F(1,26) = 0.20$, $p = 0.66$, partial eta squared = 0.01, or betweens subject differences, $F(1,26) = 1.83$, $p = 0.19$, partial eta squared = 0.07.

Taken together, the intervention did not significantly change the standard deviation of horizontal eye gaze prior to the auditory working memory task; although there was a large effect size for the waitlist control and combined groups. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes.

Dual Task. A paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the standard deviation of horizontal eye gaze (Figure 10). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention for the total sample, $t(15) = -0.50$, $p = 0.62$, $d = 0.02$, or the sample when outliers were removed, $t(13) = 0.01$, $p = 0.99$, $d < 0.01$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = 0.25$, $p = 0.81$, $d = 0.01$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(14) = -1.15$, $p = 0.27$; however, there was a moderate effect size, $d = 0.09$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = -0.62$, $p = 0.56$; but there was a moderate effect size, $d = 0.07$. The same pattern remained when outliers were removed, $t(13) = -0.81$, $p = 0.43$; but with a moderate effect size, $d = 0.05$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention, $t(30) = -1.06$, $p = 0.30$, $d = 0.04$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(15) = 0.16$, $p = 0.99$, $d < 0.01$, or when outliers were removed, $t(27) = -0.50$, $p = 0.62$, $d = 0.01$.

Analyses between visits among the waitlist control group (see Table 10) showed that there was no significant change in scores between visits for the total group, $F(2,13) = 0.84$, $p = 0.45$; with a medium effect size, partial eta squared = 0.11. This was also true when outliers were removed, $F(2,10) = 0.75$, $p = 0.50$; with a medium effect size, partial

eta squared = 0.13. For a depiction of change in scores, please refer to Figure 14. The same pattern held when the sample was reduced to those that had completed the minimum of 480 minutes of training, F (2,4) = 0.69, p = 0.55; although there was a large effect size, partial eta squared = 0.26.

Figure 15 presents the standard deviation of horizontal eye gaze during the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was no significant interaction between group and time, $F(1,29) = 0.14$, $p = 0.71$, partial eta squared = 0.01, or main effect for time, $F(1,29) = 1.29$, $p = 0.27$, partial eta squared = 0.04. No between-subjects group effect was noted either, $F(1,29) = 0.13$, $p = 0.73$, partial eta squared = 0.004. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,13) = 1.18$, $p = 0.30$, partial eta squared = 0.08. There was no main effect for time, $F(1,14) = 0.64$, $p = 0.44$, partial eta squared = 0.04 or differences between groups, $F(1,14) = 0.10$, $p = 0.75$, partial eta squared = 0.01. When outliers were removed, there was no significance: no interaction, $F(1,25) = 0.21$, $p = 0.65$, partial eta squared = 0.01, no main effect for time, $F(1,25) = 0.66$, $p = 0.70$, partial eta squared = 0.01, or betweens subject differences, $F(1,25) = 0.40$, $p = 0.53$, partial eta squared = 0.02.

Taken together, the intervention did not significantly change the standard deviation of horizontal eye gaze during the auditory working memory task; although, there was a large effect size for the waitlist control group. There was no change for the waitlist control group's standard deviation of horizontal eye gaze across the three visits.

In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes.

Post-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of horizontal eye gaze (Figure 10). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention, $t(15) = -0.94$, $p = 0.36$, $d = 0.06$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = -0.51$, $p = 0.62$, $d = 0.03$, or when outliers were removed, $t(14) = -0.30$, $p = 0.77$, $d = 0.01$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention in the total sample, $t(14) = 0.04$, $p = 0.97$, $d < 0.01$, or when the outliers were removed, $t(13) = 0.01$, $p = 0.99$, $d < 0.01$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 0.56$, $p = 0.60$; but with a moderate effect size, $d = 0.06$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention, $t(30) = -0.62$, $p = 0.54$, $d = 0.01$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(15) = -0.04$, $p = 0.97$, $d < 0.01$, or when outliers were removed, $t(28) = -0.16$, $p = 0.87$, $d < 0.01$.

Figure 15 presents the standard deviation of horizontal eye gaze after the auditory working memory task between groups during their first two visits. A mixed ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant

interaction between group and time, $F(1,29) = 0.62$, $p = 0.44$, partial eta squared = 0.02 nor main effect for time, $F(1,29) = 0.20$, $p = 0.66$, partial eta squared = 0.01. No between subjects differences were noted either, $F(1,29) = 1.97$, $p = 0.17$, partial eta squared = 0.06. For those that completed the minimum 480 minutes of training, there was neither a significant interaction between group and time, $F(1,14) = 0.001$, $p = 0.98$, partial eta squared = 0.0 nor a main effect for time, $F(1,14) = 0.22$, $p = 0.65$, partial eta squared = 0.02. However, there were significant differences between groups, $F(1,14) = 5.44$, $p = 0.04$, partial eta squared = 0.28. Looking specifically at visit 1, the control ($M = 0.13$, $SD = 0.03$) had a statistically significant higher standard deviation of horizontal eye gaze than the intervention group ($M = 0.09$, $SD = 0.03$). When outliers were removed, there was no significance: no interaction, $F(1,26) = 0.05$, $p = 0.83$, partial eta squared < 0.01, no main effect for time, $F(1,26) = 0.03$, $p = 0.88$, partial eta squared < 0.01, or betweens subject differences, $F(1,26) = 0.60$, $p = 0.45$, partial eta squared = 0.02.

Taken together, the intervention did not significantly change the standard deviation of horizontal eye gaze after the auditory working memory task. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes.

3.3.2 Comparisons of vertical eye gaze during the auditory working memory task while driving. Participants' eye gaze was measured in standard deviation in vertical eye gaze (Table 7). Eye gaze was measured at 3 time points: pre-task, during the task, and post-task (Figure 11). A repeated measure on the combined groups for Visit 1 was performed across these three time points of the task and showed no significant difference in vertical eye gaze, $F(2,29) = 0.35$, $p = 0.71$, partial eta squared = 0.02. This suggests

that the cognitive task was not restricting the eye-gaze and thus may not be suggestive of divided attention. This same pattern held for those that completed the minimum 480 minutes of training, as the changes were not significant, $F(2,14) = 0.99$, $p = 0.93$, partial eta squared = 0.01.

Pre-Task. A paired-samples t-test was used to evaluate the impact of the intervention on participants' scores on the standard deviation of vertical eye gaze (Figure 11). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention, $t(14) = 0.15$, $p = 0.88$, $d < 0.01$. This effect again did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(8) = -0.17$, $p = 0.87$, $d < 0.01$, or when outliers were removed, $t(13) = -0.217$, $p = 0.98$, $d < 0.01$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(13) = -1.00$, $p = 0.34$; but with a moderate effect size, $d = 0.07$. The same pattern emerged when outliers were removed, $t(13) = -1.00$, $p = 0.34$; but with a moderate effect size, $d = 0.07$.This effect again did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 0.34$, $p = 0.75$, $d = 0.02$. There was no significant change in standard deviation in eye gaze after intervention for the total sample that received the training, $t(28) = -0.84$, $p = 0.41$ $d = 0.02$, or when outliers were removed, $t(27) = -0.92$, $p = 0.37$, $d = 0.03$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(14) = 0.15$, $p = 0.88$, $d < 0.01$.

Figure 16 presents the standard deviation of vertical eye gaze prior to the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,28) = 1.25$, $p = 0.27$, partial eta squared = 0.04, nor main effect for time, $F(1,28) = 1.05$, $p = 0.32$, partial eta squared = 0.04. No between subjects differences were noted either, $F(1,28) = 0.22$, $p = 0.64$, partial eta squared = 0.01. For those that completed the minimum 480 minutes of training, there was neither a significant interaction between group and time, $F(1,13) = 0.13$, $p = 0.72$, partial eta squared = 0.01, nor was there a main effect for time, $F(1,13) = 0.03$, $p = 0.86$, partial eta squared = 0.002. When outliers were removed, there was no significance: no interaction, $F(1,24) = 0.17$, $p = 0.69$, partial eta squared = 0.01, no main effect for time, $F(1,24) = 0.15$, $p = 0.70$, partial eta squared = 0.01, or betweens subject differences, $F(1,24) = 0.89$, $p = 0.34$, partial eta squared = 0.04.

Taken together, the intervention did not significantly change the standard deviation of vertical eye gaze prior to the auditory working memory task. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes.

<u>Dual Task.</u> A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of vertical eye gaze (Figure 11). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention, $t(15) = -0.58$, $p = 0.57$, $d = 0.02$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of

training, $t(9) = -0.76$, $p = 0.47$, but with a moderate effect size, $d = 0.06$. When outliers were removed, there was no significance, $t(14) = -1.21$, $p = 0.25$, however, there was a moderate effect size, $d = 0.09$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(15) = -1.30$, $p = 0.21$; however, there was a moderate effect size, $d = 0.10$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(6) = 0.29$, $p = 0.78$, $d = 0.01$.When outliers were removed, this trend remained, $t(14) = -0.84$, $p = 0.42$, $d = 0.05$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention, $t(31) = -1.36$, $p = 0.18$, but there was a moderate effect size, $d = 0.06$. A similar pattern emerged when outliers were removed, $t(29) = -1.47$, $p = 0.15$, with a moderate effect size, $d = 0.07$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(15) = -0.53$, $p = 0.60$ $d = 0.02$.

Analyses between visits among the waitlist control group (see Table 10) showed that there was no significant change in scores between visits for both the total sample, $F(2,14) = 1.00$, $p = 0.40$, and when outliers were removed, $F(2,11) = 0.55$, $p = 0.59$; although there were moderate effect sizes, for the total sample (partial eta squared = 0.13) and when outliers were removed (partial eta squared = 0.09). For a depiction of change in scores, please refer to Figure 14. The same pattern held when the sample was reduced to those that had completed the minimum of 480 minutes of training, $F(2,5) = 0.60$, $p =$

0.59; while now there was a large effect size, partial eta squared = 0.20. This suggests that intervention is not significantly changing eye gaze.

Figure 16 presents the standard deviation of vertical eye gaze during the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,30) = 0.60$, $p = 0.44$, partial eta squared = 0.02, nor main effect for time, $F(1,30) = 2.10$, $p = 0.16$, partial eta squared = 0.07. No between subjects differences were noted either, $F(1,30) = 1.11$, $p = 0.30$, partial eta squared = 0.04. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,15) = 0.02$, $p = 0.88$, partial eta squared = 0.002, no main effect for time, $F(1,15) = 1.40$, $p = 0.26$, partial eta squared = 0.002, and no significant differences between groups, $F(1,15) = 1.90$, $p = 0.19$, partial eta squared = 0.11. When outliers were removed, there was no significance: no interaction, $F(1,26) = 1.12$, $p = 0.28$, partial eta squared = 0.04, no main effect for time, $F(1,26) = 0.49$, $p = 0.49$, partial eta squared = 0.02, or betweens subject differences, $F(1,26) = 0.14$, $p = 0.71$, partial eta squared = 0.01.

Taken together, the intervention did not significantly change the standard deviation of vertical eye gaze during the auditory working memory task, although there was a large effect size for the larger waitlist control sample. There was no change for the waitlist control group's standard deviation of vertical eye gaze across the three visits. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in vertical eye gaze.

Post-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of vertical eye gaze in eye gaze (Figure 11). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention for the total sample, $t(15) = -0.93$, $p = 0.37$, $d = 0.05$. This effect again did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = -0.90$, $p = 0.39$, but with a moderate effect size, $d = 0.08$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(14) = -1.62$, $p = 0.13$; however, there was a large effect size, $d = 0.16$. This effect had a similar pattern when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 1.09$, $p = 0.33$, but there was a large effect size, $d = 0.19$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention, $t(30) = 1.87$, $p = 0.07$; however, there was a large effect size, $d = 0.11$ again. However, there was only a moderate effect size, $d = 0.12$, when the sample was reduced to those that completed the minimum 480 minutes of training, $t(15) = -1.45$, $p = 0.17$.

Figure 16 presents the standard deviation of vertical eye gaze after the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,29) = 0.68$, $p = 0.42$, partial eta squared = 0.02, nor a main effect for time, $F(1,29) = 2.36$, $p = 0.14$, partial eta squared = 0.08. No between subjects differences were noted either, $F(1,29) = 0.40$, $p = 0.53$, partial

eta squared = 0.01. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,14) = 1.13$, $p = 0.31$, partial eta squared = 0.07, no main effect for time, $F(1,14) = 4.13$, $p = 0.06$, notwithstanding a large effect size, partial eta squared = 0.23; but also no significant differences between groups, $F(1,14) = 0.20$, $p = 0.66$, partial eta squared = 0.01. When outliers were removed, there was no significance: no interaction, $F(1,26) = 1.06$, $p = 0.31$, partial eta squared = 0.04, no main effect for time, $F(1,26) = 0.003$, $p = 0.96$, partial eta squared < 0.01, or betweens subject differences, $F(1,26) = 0.40$, $p = 0.53$, partial eta squared = 0.02.

Taken together, the intervention did not significantly change the standard deviation of vertical eye gaze after the auditory working memory task, but may be an artifact of small sample size given the large effect sizes for the waitlist control and combined groups. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in vertical eye gaze.

3.3.3 Comparisons of horizontal eye gaze during the visual working memory task while driving. Participants' eye gaze was measured with standard deviation of horizontal eye gaze (Table 8). Eye gaze was measured at 3 time points: pre-task, during the task, and post-task (Figure 12). A repeated measure on the combined groups for Visit 1 was performed across these three time points of the task and showed a significant difference in horizontal eye gaze, $F(2,28) = 22.84$, $p < 0.001$, partial eta squared = 0.62. There were significant differences between pre-task and post-task when compared to during the task, with $p < 0.001$ for both. This suggests that the cognitive task was restricting horizontal eye-gaze and suggestive of divided attention. This same pattern held true for those that completed the minimum 480 minutes of training, as there were significant changes across

the phases of the task, $F(2,13) = 8.64$, $p = 0.004$, partial eta squared = 0.57. However, there were not only significant differences between pre-task and during ($p = 0.01$) as well as pre-task and post-task ($p = 0.03$), but also differences between post-task and during ($p = 0.001$).

Pre-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of horizontal eye gaze (Figure 12). For the DriveSharp™ group, there was a significant change in standard deviation after intervention in the total sample, $t(15) = -3.62$, $p = 0.03$, $d = 0.47$. The standard deviation after intervention ($M = 0.11$, $SD = 0.03$) increased from baseline ($M = 0.09$, $SD = 0.03$). This effect remained the same when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = -3.39$, $p = 0.01$, $d = 0.56$. The standard deviation after intervention ($M = 0.11$, $SD = 0.03$) increased from baseline ($M = 0.09$, $SD = 0.04$). For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation after intervention, $t(15) = -0.94$, $p = 0.36$, but a moderate effect size, $d = 0.06$. This effect again was not significant when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 0.13$, $p = 0.90$, $d < 0.01$. For the total sample that received the training, there was a significant increase in standard deviation after intervention, $t(31) = -2.63$, $p = 0.01$, $d = 0.18$. The standard deviation after intervention ($M = 0.12$, $SD = 0.04$) increased from baseline ($M = 0.10$, $SD = 0.04$). This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(14) = -1.30$, $p = 0.21$; however, there was a moderate effect size, $d = 0.10$.

Figure 17 presents the standard deviation of horizontal eye gaze prior to the visual working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1 visit 2) was conducted. There was no significant interaction between group and time, $F(1,30) = 0.05$, $p = 0.83$, partial eta squared = 0.002. However, there was a main effect for time, $F(1,30) = 20.01$, $p < 0.001$, partial eta squared = 0.40, but no between subjects differences were noted, $F(1,30) = 3.16$, $p = 0.09$; despite a medium effect size, partial eta squared = 0.10. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,15) = 0.01$, $p = 0.94$, partial eta squared < 0.01; however, there was a main effect for time, $F(1,15) = 10.97$, $p = 0.01$, partial eta squared = 0.42, but there were significant differences between groups, $F(1,15) = 3.01$, $p = 0.10$; and a large effect size, partial eta squared = 0.17. When outliers were removed, there was no significance: no interaction, $F(1,29) = 0.53$, $p = 0.82$, partial eta squared < 0.01. While, there was a main effect for time, $F(1,29) = 18.86$, $p < 0.001$, partial eta squared = 0.39, but no betweens subject differences, $F(1,29) = 2.04$, $p = 0.16$, partial eta squared = 0.07.

Taken together, the intervention significantly increased the standard deviation of horizontal eye gaze prior to the visual working memory task for the DriveSharp™ and combined groups. In addition, when groups were compared (control vs. DriveSharp™), the presence of a time difference with no between subject differences might speak to practice effects.

Dual Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of horizontal eye gaze (Figure 12). For the

DriveSharp™ group, there was no significant change in standard deviation after intervention, *t*(15) = -0.78, *p* = 0.45, *d* = 0.04. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, *t*(9) = -0.73, *p* = 0.49, but with a moderate effect size, *d* = 0.06. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation after intervention, *t*(13) = -1. 58, *p* = 0.14; however, there was a large effect size, *d* = 0.16. This same pattern remained when outliers were removed, *t*(12) = -2.05, *p* = 0.06; and, there was a large effect size, *d* = 0.26. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, *t*(5) = -0.77, *p* = 0.49; but there was a moderate effect size, *d* = 0.13. For the total sample that received the training, there was no significant change in standard deviation after intervention, *t*(29) = -1.66, *p* = 0.11; however, there was a moderate effect size, *d* = 0.09. This pattern remained the same when outliers were removed, *t*(28) = -1. 92, *p* = 0.07; however, there was a moderate effect size, *d* = 0.12. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, *t*(14) = -1.05, *p* = 0.31, but there was a moderate effect size, *d* = 0.07.

Analyses between visits among the waitlist control group (see Table 10) showed that there was no significant change in scores between visits, *F*(2,12) = 2.87, *p* = 0.10; but there was a large effect size, partial eta squared = 0.32. For a depiction of change in scores, please refer to Figure 14. A similar pattern emerged when outliers were removed, *F* (2,10) = 1.25, *p* = 0.33, and a large effect size, partial eta squared = 0.20. When the

sample was reduced to those that had completed the minimum of 480 minutes of training, F (2,3) = 0.22, p = 0.82; although now a moderate effect size, partial eta squared = 0.13.

Figure 17 presents the standard deviation in horizontal eye gaze during the visual working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, F(1,28) = 0.10, p = 0.76, partial eta squared = 0.003, nor for time, F(1,28) = 1.72, p = 0.20, but with a medium effect size, partial eta squared = 0.06. No between subjects differences were noted either, F(1,28) = 0.15, p = 0.70, partial eta squared = 0.01. For those that completed the minimum 480 minutes of training, there was no significant interaction between groups and time, F(1,13) = 0.60, p = 0.45, partial eta squared = 0.04, or main effect for time, F(1,13) = 2.20, p = 0.16; however, there was a large effect size, partial eta squared = 0.15. However, there were no significant differences between groups, F(1,13) = 0.39, p = 0.54, partial eta squared = 0.03. When outliers were removed, there was no significance: no interaction, F(1,26) = 0.09, p = 0.76, partial eta squared < 0.01, no main effect for time, F(1,26) = 0.83, p = 0.37, partial eta squared = 0.03, and no betweens subject differences, F(1,26) = 0.70, p = 0.41, partial eta squared = 0.03.

Taken together, the intervention did not significantly increased the standard deviation of horizontal eye gaze during the visual working memory task for the DriveSharp™ group but demonstrated large effect sizes for the waitlist control and combined groups. The reduced samples of those that completed the minimum hours of training, demonstrated large effect sizes. There was no change for the waitlist control

group's standard deviation of horizontal eye gaze across the three visits. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in horizontal eye gaze.

Post-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of horizontal eye gaze (Figure 12). For the DriveSharp™ group, there was no significant change in standard deviation of eye gaze after intervention, $t(15) = 0.71$, $p = 0.49$, $d = 0.03$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = 0.02$, $p = 0.98$, $d < 0.01$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation of eye gaze after intervention, $t(14) = -1.73$, $p = 0.11$; however, there was a large effect size, $d = 0.18$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 0.12$, $p = 0.91$, $d < 0.01$. For the total sample that received the training, there was no significant change in standard deviation after intervention, $t(30) = -1.03$, $p = 0.31$, $d = 0.03$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(15) = 0.12$, $p = 0.90$, $d < 0.001$.

Figure 17 presents the standard deviation of horizontal eye gaze after the visual working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,29) = 2.20$, $p = 0.15$, but a medium

effect size, partial eta squared = 0.07, nor was there a significant finding for time, $F(1,29) = 0.47$, $p = 0.50$, partial eta squared = 0.02. No between subjects differences were noted either, $F(1,29) = 2.36$, $p = 0.14$; although there was a medium effect size, partial eta squared = 0.08. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,14) = 0.15$, $p = 0.70$, partial eta squared = 0.01, or a main effect for time, $F(1,14) = 0.14$, $p = 0.72$, partial eta squared = 0.01. There were also no significant differences between groups, $F(1,14) = 2.80$, $p = 0.12$, but there was a large effect size, partial eta squared = 0.17. When outliers were removed, there was no significance in terms of interaction, $F(1,27) = 0.77$, $p = 0.39$, partial eta squared = 0.03, no main effect for time, $F(1,27) = 0.002$, $p = 0.96$, partial eta squared < 0.01, and no betweens subject differences, $F(1,27) = 1.16$, $p = 0.29$, partial eta squared = 0.04.

Taken together, the intervention did not significantly change the standard deviation of horizontal eye gaze after the visual working memory task, with the exception of a large effect size for the waitlist control group. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in horizontal eye gaze.

3.3.4 Comparisons of vertical eye gaze during the visual working memory task while driving. Participants' eye gaze was measured in standard deviation in vertical eye gaze (Table 9). Eye gaze was measured at 3 time points: pre-task, during the task, and post-task (Figure 13). A repeated measure on the combined groups for Visit 1 was performed across these three time points of the task and showed a significant difference in vertical eye gaze, $F(2,28) = 4.30$, $p = 0.02$, partial eta squared = 0.23; however, given

where there were significant differences between all phases of the task (*p* = 0.003 comparing both pre- with during and post-task; *p* = 0.004 comparing pre-task and during), it may not be suggestive of divided attention. This same pattern held for those that completed the minimum 480 minutes of training, as the changes were not significant, $F(2,13) = 6.28$, $p = 0.01$, partial eta squared = 0.49.

Pre-Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of vertical eye gaze (Figure 13). For the DriveSharp™ group, there was no significant change in standard deviation after intervention, $t(15) = -0.85$, $p = 0.41$, $d = 0.05$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = -0.95$, $p = 0.37$; however, there was a large effect size, $d = 0.09$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(15) = -1.20$, $p = 0.25$, while there was a moderate effect size, $d = 0.09$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(6) = -0.11$, $p = 0.92$ $d < 0.01$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention, $t(31) = -1.43$, $p = 0.16$, but with a moderate effect size, $d = 0.06$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(16) = -0.86$, $p = 0.40$, $d = 0.01$.

Figure 18 presents the standard deviation of vertical eye gaze prior to the visual working memory task between groups during their first two visits. A mixed-model

ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,30) = 0.10$, $p = 0.76$ partial eta squared = 0.003, nor a main effect for time, $F(1,30) = 1.67$, $p = 0.21$, partial eta squared = 0.05. No between subjects differences were noted either, $F(1,30) = 2.71$, $p = 0.11$; but there was a medium effect size, partial eta squared = 0.08. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,15) = 0.72$, $p = 0.41$, partial eta squared = 0.05, no main effect for time, $F(1,15) = 0.15$, $p = 0.70$, partial eta squared = 0.01, and no significant differences between groups, $F(1,15) = 1.48$, $p = 0.24$; and again a medium effect size, partial eta squared = 0.09**.** When outliers were removed, there was no significance in terms of interaction, $F(1,28) = 0.30$, $p = 0.59$, partial eta squared = 0.01, no main effect for time, $F(1,28) = 0.45$, $p = 0.51$, partial eta squared = 0.02, and no betweens subject differences, $F(1,28) = 0.66$, $p = 0.42$, partial eta squared = 0.02.

Taken together, the intervention did not significantly change the standard deviation of vertical eye gaze prior to the visual working memory task. However, there were large effect sizes for the reduced sample of DriveSharp™ and the entire combined sample. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in horizontal eye gaze.

Dual Task. A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of vertical eye gaze (Figure 13). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze after intervention, $t(15) = -0.31$, $p = 0.76$, $d = 0.01$. This same pattern emerged when

outliers were removed, $t(14) = -0.78$, $p = 0.13$, $d = 0.04$, and when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = 0.14$, $p = 0.89$, $d < 0.01$. For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was a significant increase in standard deviation in eye gaze after intervention, $t(13) = -2.33$, $p = 0.04$, $d = 0.29$, which is a large effect size. The standard deviation in eye gaze after intervention ($M = 0.06$, $SD = 0.02$) increased from baseline ($M = 0.05$, $SD = 0.02$). This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = -0.74$, $p = 0.50$, although there was a moderate effect size, $d = 0.12$. For the total sample that received the training, there was not a significant change in standard deviation in eye gaze after intervention, $t(29) = -1.49$, $p = 015$, $d = 0.07$, which is a moderate effect size. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(14) = -0.26$, $p = 0.80$, $d < 0.01$.

Analyses between visits among the waitlist control group (see Table 10) showed that there was no significant change in scores between visits, $F(2,12) = 2.87$, $p = 0.10$; although there was a large effect size, partial eta squared = 0.32. For a depiction of change in scores, please refer to Figure 14. This same pattern emerged when outliers were removed, $F(2,11) = 2.13$, $p = 0.17$; although there was a large effect size, partial eta squared = 0.28. The same pattern held when the sample was reduced to those that had completed the minimum of 480 minutes of training, $F(2,3) = 0.22$, $p = 0.82$, partial eta squared = 0.13.

Figure 18 presents the standard deviation of vertical eye gaze during the visual working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (visit 1, visit 2) was conducted. There was neither a significant interaction between group and time, $F(1,28) = 1.13$, $p = 0.30$, partial eta squared = 0.04, nor a main effect for time, $F(1,28) = 2.21$, $p = 0.15$, partial eta squared = 0.07. No between subjects differences were noted either, $F(1,28) = 0.04$, $p = 0.85$, partial eta squared = 0.001. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and time, $F(1,13) = 0.26$, $p = 0.62$, partial eta squared = 0.02, no main effect for time, $F(1,13) = 0.13$, $p = 0.73$, partial eta squared = 0.01, and no significant differences between group, $F(1,13) = 0.11$, $p = 0.74$, partial eta squared = 0.01. When outliers were removed, there was no significance in terms of interaction, $F(1,26) = 0.08$, $p = 0.79$, partial eta squared < 0.01, no main effect for time, $F(1,26) = 2.06$, $p = 0.16$, partial eta squared = 0.07, and no betweens subject differences, $F(1,26) = 0.34$, $p = 0.56$, partial eta squared = 0.01.

Taken together, the intervention did significantly change the standard deviation of vertical eye gaze during the visual working memory task for the waitlist control group. There was no change for the waitlist control group's standard deviation of horizontal eye gaze across the three visits. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in vertical eye gaze.

<u>Post-Task.</u> A paired-samples t-test was used to evaluate the impact of the intervention on the standard deviation of vertical eye gaze (Figure 13). For the DriveSharp™ group, there was no significant change in standard deviation in eye gaze

after intervention, $t(15) = -0.34$, $p = 0.74$, $d = 0.01$. This effect did not reach significance when the sample was reduced to those that completed the minimum 480 minutes of training, $t(9) = -0.39$, $p = 0.70$, $d = 0.02$. Although when outliers were removed, there was s still no significance, $t(14) = -1.62$, $p = 0.13$; but there was a large effect seize, $d = 0.16$, For the waitlist control group who subsequently underwent the DriveSharp™ training (comparison between visits 1 and 3), there was no significant change in standard deviation in eye gaze after intervention, $t(14) = -0.52$, $p = 0.61$, $d = 0.02$. This effect was not significant when the sample was reduced to those that completed the minimum 480 minutes of training, $t(5) = 0.50$, $p = 0.64$, $d = 0.05$. For the total sample that received the training, there was no significant change in standard deviation in eye gaze after intervention for the total sample, $t(30) = -0.60$, $p = 0.55$, $d = 0.01$, or for those that completed the minimum 480 minutes of training, $t(15) = -0.12$, $p = 0.91$, $d < 0.01$. However, when outliers were removed there was a moderate effect size, $t(29) = -1.56$, $p = 0.13$, $d = 0.08$. This effect did not reach significance when the sample was reduced to those that Figure 18 presents the standard deviation of vertical eye gaze after the visual working memory task between groups during their first two visits. A mixed-model ANOVA with one between subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (pre-test, post-test) was conducted. There was no significant interaction between group and time, $F(1,29) = 1.23$, $p = 0.28$, partial eta squared = 0.04, or main effect for time, $F(1,29) = 2.44$, $p = 0.13$; but a medium effect size, partial eta squared = 0.08. No between subjects differences were noted either, $F(1,29) = 0.86$, $p = 0.36$, partial eta squared = 0.03. For those that completed the minimum 480 minutes of training, there was no significant interaction between group and

time, $F(1,14) = 0.06$, $p = 0.81$, partial eta squared = 0.004; and. no main effect for time, $F(1,14) = 0.57$, $p = 0.46$, partial eta squared = 0.04, nor significant differences between group, $F(1,14) = 1.19$, $p = 0.29$, despite the medium effect size, partial eta squared = 0.08. When outliers were removed, there was no significant interaction, $F(1,28) = 0.46$, $p = 0.50$, partial eta squared = 0.02. However, there was a main effect for time, $F(1,28) = 5.60$, $p = 0.03$, partial eta squared = 0.17, with no betweens subject differences, $F(1,28) = 1.08$, $p = 0.31$, partial eta squared = 0.04.

Taken together, the intervention did not significantly change the standard deviation of vertical eye gaze after the visual working memory task, but the waitlist control group did demonstrate a large effect size. There was no change for the waitlist control group's standard deviation of horizontal eye gaze across the three visits. In addition, when groups were compared (control vs. DriveSharp™), there were no significant changes in horizontal eye gaze.

3.3.5 Comparisons of accuracy on working memory tasks while driving at baseline and after training with DriveSharp™. Table 11 describes the data for the accuracy of performance during the working memory tasks.

Auditory Working Memory. Figure 19 presents the performance accuracy for the auditory working memory task between groups during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (pre-test, post-test) was conducted. There was no significant interaction between group and testing, $F(1,29) = 0.58$, $p = 0.45$, partial eta squared = 0.02. There was no main effect for testing, $F(1,29) = 0.15$, $p = 0.70$, partial eta squared = 0.01, and no differences between group, $F(1,29) = 0.73$, $p = 0.40$, partial eta

squared = 0.03, suggesting no difference in effectiveness of the intervention. For those that completed the minimum 480 minutes of training, again there was no significant interaction between group and time, $F(1,14) = 2.17$, $p = 0.16$; but a medium effect size, partial eta squared = 0.13. There was no main effect for time or between group differences, suggesting no effectiveness of the intervention.

Visual Working Memory. Figure 20 presents the performance accuracy for the visual working memory task between group during their first two visits. A mixed-model ANOVA with one between-subjects factor of group (DriveSharp™, Control) and one within-subjects factor of testing (pre-test, post-test) was conducted. There was no significant interaction between group and testing $F(1,30) = 1.40$, $p = 0.25$, partial eta squared = 0.05. There was a main effect for testing, $F(1,30) = 4.56$, $p = 0.04$, with a medium effect size, partial eta squared = 0.13, and no differences between group, $F(1,30) = 0.75$, $p = 0.39$, partial eta squared = 0.02, suggesting no effectiveness of the intervention. For those that completed the minimum 480 minutes of training, again there was no significant interaction between group and time, $F(1,15) = 0.16$, $p = 0.695$, partial eta squared = 0.011. There was no main effect for time or between group differences, suggesting no effectiveness of the intervention.

Taken together, the intervention did not significantly change the accuracy of performance of either the auditory or visual working memory tasks. Of note, the visual working memory task's accuracy improved significantly between visits, however, there were no group differences suggesting that this may be a practice effect.

CHAPTER 4

DISCUSSION

The present study examined the relationship of a computer-based training program, specifically DriveSharp™, and performance on an on-road driving paradigm in a normal aging sample. Participants, ranging in ages 60-75 and randomly assigned to the treatment group, completed the DriveSharp™ as did, subsequently, a wait-list control group. All participants completed baseline assessments using the RBANS on which there were no differences between groups at baseline. Pre- and post-intervention measures included both standardized neuropsychological tests and experimental tasks of visual attention, as well as recordings of participants' eye movements as they performed specific cognitive tasks while driving. The two principal aims of the present study addressed, first whether training on DriveSharp™ could improve cognitive performance as measured by standardized and laboratory tasks of visual attention, and, second, whether the effects, if any, of such training would transfer to real-time driving. I will first discuss the findings related to DriveSharp™ and performance on standardized and laboratory tasks of visual attention followed by the eye movement data related to real-time driving.

4.1 DriveSharp™ and Cognitive Performance

Visual attention is not only amenable to improvement with speed-of-processing training (K. Ball, et al., 2002; K. Ball, et al., 2007; Willis, et al., 2006; Fredric D. Wolinsky, et al., 2006) but it is also the primary cognitive construct being utilized during

driving. It is a multi-faceted cognitive domain that requires an individual to focus on the selection of a region of interest in the visual field, the selection of feature dimensions and values of interest, the control of information flow through the network of neurons that constitutes the visual system, and the shifting from one selected region to the next in time (Tsotsos, et al., 2001). These facets map onto the psychological model of driving behavior as it relates to older driver crash risk, which conceptualizes driving at three hierarchical levels (Michon, 1989). The top level involves strategic processes (e.g., route choice or consideration of road traffic rules); the middle tactical level involves planning actions or adapting to the movements of other drivers; and last, at the lowest level is action execution and perceptual processing. Declines in this lower level, which could include UFOV (K. Ball & Owsley, 1991; Bolstad & Hess, 2000) and psychomotor abilities (Eby, Trombley, Molnar, & Shope, 1998), are associated with crash risk. The reason for such is that a driver is required to attend to relevant objects all the while needing the ability to switch attention voluntarily between objects. These same abilities diminish with age as the connectivity between regions changes (Rypma, et al., 2006). This forms the foundation for both utilizing a cognitive training program of visual attention and neuropsychological tests that measure this construct.

As individuals age, perceptual speed, attentional functions (e.g. vigilance, concentration, visual scanning), and visuo-spatial ability change. A test like Trailmaking A or C, which requires individuals to connect the dots in numerical order and measures psychomotor speed and visual scanning, would likely be impacted by these factors (Wahlin, Backman, Wahlin, & Winblad, 1996). Therefore it is understandable why this measure has been shown to have moderate correlations to driving outcome measures

(Fox, et al., 1997; B. L. Mazer, et al., 1998). Given this, it was hypothesized that after training, individuals would show significant decreases in time to completion on Trailmaking A or C. In keeping with previous research (Edwards, Wadley, et al., 2005), the results of the current study indicated significant differences among the combined group for both time to completion and on standardized scores normed against other people at the same age. These results occur in the context of alternate versions of the Trailmaking A or C to avoid group practice effects. In theory, significant improvement on this measure would translate to improved psychomotor speed and visual search, which given the psychological model of crash risk could be argued to lead to a reduction in risk for these individuals.

It also has been shown that older adults show an age-related deficit in performing dual tasks (Hartley, 2001) and this relates to three sources: general slowing, process-specific slowing, and the use of a more cautious task coordination strategy during dual tasks (J. M. Glass, et al., 2000). With that in mind, a task like Trailmaking B and D that measures cognitive flexibility by asking an individual to inhibit a dominant response while maintaining set has been used often as a measure of dual-processing. Research has shown that not only do older individuals have more difficulty on Trailmaking B or D (Salthouse, Atkinson, & Berish, 2003; Van Gorp, Satz, & Mitrushina, 1990) but performance has also been shown to improve with intervention (Edwards, Wadley, et al., 2005) and correlate with reduced crash risk (K. K. Ball, et al., 2006; Staplin, et al., 2003). Thus, it was hypothesized that time to completion on this measure would significantly decrease after intervention. The results of the current study did not support this although there were large effect sizes for time for completion in the combined group with

minimum of 480 minutes and training and z-scores for the combined groups in the larger and smaller samples (minimum 480 minutes of training), suggesting a large difference between means. Another study in a sample of individuals who incurred a stroke also did not show significant findings on this measure after a speed-of-processing intervention (B. L. Mazer, et al., 2003).

As mentioned previously, visual attention decreases with age. The UFOV test, which is the most widely used test of visual attention, measures three subdomains of attention: processing speed, divided attention, and selective attention. Each of these measures the speed at which one can rapidly process multiple stimuli across the visual field. It is highly correlated with other laboratory measures of visual attention (K. Ball, et al., 2002) and crash risk (Bedard, et al., 2006; Goode, et al., 1998). Given this, it was hypothesized that individuals would improve their reaction times on all subdomains of UFOV. Overall, measures of UFOV showed the most robust changes. For example, divided attention significantly decreased in the DriveSharp™ group for the larger sample and those that completed the minimum 480 minutes of training; and, there were large effect sizes for the combined group. Selective attention showed a similar pattern with significant differences in the DriveSharp™ group in both the total sample and those who completed the minimum 480 minutes of training. In the latter sample, the combined group also showed significant findings and a large effect size for the waitlist control group. These findings should be interpreted with caution for the total sample, as there appear to be baseline differences between DriveSharp™ and the waitlist control groups at baseline. These improvements suggest that individuals are better able to respond simultaneously to multiple tasks. For example, improvements in selective attention,

which is under the umbrella of executive function, suggests an improved ability to maintain a set in the face of distracting or competing stimuli. Divided (K. K. Ball, et al., 2006) and selective attention (Parasuraman & Nestor, 1991) have been associated with older driver crash risk. Thus, improvements in these domains may lead to reductions in crash risk. Taken together, these improvements show a lot of promise for the impact of training on older drive safety. This is also the first study to utilize a waitlist control design, which thereby provided us with information on possible practice effects. Given the pattern of scores across three visits, it appears as though the observed effects were likely the result of intervention and not practice since the significant changes occurred between visits 1 and 3.

In contrast to this rather promising finding, UFOV processing speed only showed significant reduction in reaction time with training in the combined group while the remaining groups showed moderate to large effect sizes. The sample in the present study performed close to ceiling (16.7 msec is the lowest, best performance) at baseline and therefore had little room for significant improvement. These findings may also differ and not be as robust as compared to other studies because of differences in sample. Other studies relied solely on the measure of processing speed in samples with reduced processing speed at baseline, and thus reported significant improvements in that UFOV domain (Edwards, Myers, et al., 2009; Roenker, et al., 2003). With other studies it is unclear what aspect of UFOV was improvement as they cited general improvement on UFOV (Edwards, Wadley, et al., 2005; Vance, et al., 2007). In summary, the significance of improvement on divided and selected attention truly speaks to the deficits normally

seen with aging and provides hope that training can improve these domains, particularly as it relates to driving.

While the UFOV has been used extensively, the ANT, which is another measure of visual attention, has not. The ANT conflict condition involves monitoring and resolving competing responses, and thus measures abilities that falls within the inhibition domain of executive function. The premise of the task is that when distracters (conflict responses) are presented, they compete for response selection, thereby increasing reaction time. Studies have shown that the ANT measures a core cognitive construct underlying driving and been correlated with the UFOV in driving simulation (Weaver, et al., 2009). Given this, it was hypothesized that intervention would lead to significantly reduced reaction times for both the conflict condition and more generally, the average reaction time across the ANT task. Significant reductions were observed in conflict and average reaction times. However, performance across visits for the waitlist control group did not show a clear improvement devoid of practice effects. As such, it is unclear how much training itself played a role in improvement. However, an improvement in reaction time would in theory relate to better processing of visual stimuli and perhaps improved multitasking and reaction time for stopping or reacting in the presence of danger on the road.

4.2 DriveSharp™ and On-Road Performance

The relationship between attention and eye movement has been extensively studied (J. E. Hoffman & Subramanian, 1995; L. Hoffman, McDowd, Atchley, & Dubinsky, 2005). The neural underpinnings of saccades and visual attention, parietal, frontal, and temporal lobes, overlap with one another (Corbetta, et al., 1998; McDowell,

Dyckman, Austin, & Clementz, 2008). The present study measured eye movements through standard deviation of horizontal and vertical eye gaze. Horizontal movements relate to scanning the horizontal visual field and represent the width of attending to the visual field. On the other hand, vertical movements relate to how far one is looking ahead. In keeping with the underlying foundation of UFOV, improved UFOV could be obtained from a large standard deviation in both vertical and horizontal eye gaze resulting in a wider breadth of attention to stimuli on the road, and allow more time to react for stimuli.

Driving behaviors have been shown to have neural correlates that map onto visual attention and eye gaze regions. According to Spiers & Maguire (2007), prepared actions such as starting, turning, reversing and stopping are associated with a common neural network comprised of premotor, parietal and cerebellar regions. These regions are responsible for saccadic movement as well as visual attention (Corbetta, et al., 1998). The right lateral prefrontal cortex is specifically engaged during the processing of road traffic rules (Spiers & Maguire, 2007) as this area of the brain is generally responsible for decision-making and planning complex cognitive behaviors (Miller & Cohen, 2001) and altering responses to adapt to challenges in the environment (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Unexpected hazardous events such as swerving and avoiding collisions are associated with activation of lateral occipital and parietal regions, insula, as well as a more posterior region in the medial premotor cortex than prepared actions (Spiers & Maguire, 2007). These areas relate to reaction times and an individual's ability to react in the presence of danger (K. M. Lee, Chang, & Roh, 1999). In contrast, planning future actions and monitoring fellow road users is associated with activity in

superior parietal, lateral occipital cortices and the cerebellum (Spiers & Maguire, 2007), which maps onto brain regions responsible for visual and attentive tracking moving objects (Culham, et al., 1998). Thus, driving engages a complex set of perceptual, cognitive, and action routines that rely on widely-distributed networks of brain regions. The aforementioned regions correlate to the cognitive model of driving (Michon, 1989). The DriveSharp™ training as well as the working memory tasks during the drive likely taxes the lateral occipital and parietal regions. A caveat is that there has been not published research monitoring the changes on neuroimaging that result from DriveSharp™ or any visual attention training.

The premotor theory of attention provides a foundation for understanding the basis of tunneling vision during working memory tasks while driving. It states that covert attention, which is the act of mentally focusing on one of several possible sensory stimuli, is a result of activity within the motor systems responsible for the generation of a saccade. Attentional shifts occur during these moments when the brain is attending to several stimuli. It is these shifts that influence the timing of microsaccades (Engbert & Kliegl, 2003) and also alter neural activation (Nobre, Gitelman, et al., 2000; Nobre, Sebestyen, et al., 2000). Within this framework, attention is a by-product of the action of motor systems, and attentional effects can be associated with different motor systems or spatial coordinates. This is the underlying theory for why the control of goal-directed movements and the control of attention are closely linked as they are implemented by common structures (Rizzolatti, et al., 1994). Activity evident in the frontal cortex, concentrating in the precentral sulcus, the parietal cortex (specifically in the intraparietal sulcus), and in the lateral occipital cortex have been linked to both overt and covert

attention shifts (Beauchamp, et al., 2001). These studies clearly showed that visuospatial attention and eye movements share the same cortical neuronal network (Corbetta, et al., 1998; Nobre, Gitelman, et al., 2000) providing the basis for using eye gaze as a proxy of attention. It has also been studied extensively to measure task sharing during driving (Reimer, 2009; Reimer, et al., 2010; Sodhi, et al., 2002). The impact of this relates strongly to older drivers because an individual's capacity for managing multiple tasks simultaneously decreases with age (Joan M. McDowd & Shaw, 2000; J. M. McDowd, Vercruyssen, & Birren, 1991).

Eye gaze as it relates to divided attention has shown that gaze dispersion varies by task difficulty. Constriction appears predominantly in the horizontal plane. Vertical gaze, however, appears to move upward with increasing divided attention (Reimer, et al., 2010). Narrowing of vertical and horizontal eye gaze can be induced by having participants complete working memory tasks and are thus can be viewed as a proxy measure of demands imposed on the limited capacity of attention (Mehler, et al., 2009; Reimer, et al., 2009; Schieber & Gilland, 2008; Schlorholtz & Schrieber, 2006). This narrowing is supported by neuroimaging, which demonstrated that when auditory and visual tasks are performed concurrently, the activation volume in the cortical systems underlying the two tasks are not independent, but rather decrease relative to the single task conditions suggesting constraints (Just, et al., 2001). Underlying this is the theory of cognitive efficiency and neural connectivity (Rypma, et al., 2006). It also supports the premotor theory of attention, which underlies eye tracking as a proxy of visual attention (Corbetta, et al., 1998), particularly for visual tunneling during times of divided attention.

Previous research suggests that visual attention training leads to increased driver safety (Roenker, et al., 2003). It was hypothesized that standard deviations of horizontal eye gaze would increase and vertical eye gaze would decrease following the intervention, and more specifically during times of divided attention. Doing so would relate to increased horizontal scanning behavior and increased sight distance. Specifically, during the auditory working memory task while driving, there was more horizontal scanning behavior and more forward-looking gaze as seen by the increased standard deviation of vertical eye gaze, although these did not achieve statistical significance, but rather trends with large effect sizes for the waitlist control and combined groups. More robust changes were observed for the visual working memory task where there were significant increases in the scanning behavior post intervention prior to the task, as well as more gaze dispersion in the horizontal and vertical planes thereby increasing field of vision. Although a shift in vertical gaze is normally associated with cognitive load (Reimer, et al., 2010), in theory, this could translate to improved reaction times given possible awareness of activity further down the road or more monitoring of the dashboard. Taking the improved reaction times on neuropsychological testing and vertical eye gaze changes, these could transfer to improvements in crash occurrence given research that older adults are slower in decision-making (Walker, et al., 1997) and that slow in making unexpected decisions requiring rapid responses (Belanger, Gagnon, & Yamin, 2010). However, these results should be interpreted with caution given the possibility of practice effects and acclimation to the driving paradigm.

As noted above, standard deviations of both vertical and horizontal eye gaze showed different patterns of performance for the auditory and visual working memory tasks during the drive. The difference is supported given the neuroimaging that suggests a relative independence of function between the region for auditory (temporal regions) and visual (parietal regions) processes (Just, et al., 2001). Also important to note is that the visual working memory task is similar to the training both cognitively and neurologically. Given the goals of the training, particularly of the Jewel Diver training, which asks individuals to mentally keep track of moving jewels on the screen, these results are not surprising. Adult learning theory states adults are more successful with learning strategies that involve active practice and immersion in the domain in which they will ultimately be using the skills that they are learning (Knowles, Holton, & Swanson, 2005), which supports the idea that a task that is similar in nature would show the most robust improvement (e.g., Jewel Diver and the Clock task). Again, the premotor theory of attention states that control of goal-directed movements and the control of attention are closely linked, which may provide a theoretical and neural basis for why the visual working memory task demonstrated significant change in eye gaze after intervention. All these may explain the difference in eye gaze between visual and auditory working tasks during the drive.

4.3 Past, Present, and Future

Overall, the neuropsychological improvements, specifically psychomotor speed and divided and selected attention, suggest that with training, individuals undergoing normal cognitive aging can improve on measures of visual attention. While these results

have been shown to be in true in previous studies, the question remains as to whether these improvements translate to changes or improvements in real-life activities, specifically driving since the same unequivocal pattern has not been shown in transfer tasks. There are trends towards some improvement on on-road UFOV as measured by standard deviations of horizontal and vertical eye gaze. Given the overlap between visual attention improvement on neuropsychological testing and on-road visual allocation, it is possible that the underlying visual attention mechanisms central to safe driving may be improved. It may be that the lateral parietal and occipital regions that overlap in activation of planned and unplanned regions during driving (Spiers & Maguire, 2007), as well as in visual attention shifts (Beauchamp, et al., 2001) are at the core of these changes. It is possible that the training improves cognitive efficiency and therefore relates to improved performance on tests. The fact that there are common neurological mechanisms for these actions makes it more likely that there is something specific to the visual attention training and not a product of simple activity, such as increased social involvement, and perhaps even auditory working memory training. Also, taking in consideration previous longitudinal, large-scale studies, speed-of-processing showed the most improvement than memory or reasoning training (Willis, et al., 2006;Edwards, Wadley, et al., 2005; Owsley, Sloane, & McGwin, 2002).

While there is reason to believe that with training, individuals are scanning the road more and as well as see further down the road, the results in the context of a number of limitations, which will be discussed later. It is not clear whether training enhances plasticity in general or may only transfer to tasks that rely on behavioral and neural processes, which overlap with those of the trained task (Caserta & Abrams, 2007; Dahlin,

Neely, Larsson, & Backman, 2008). Irrespective of the reason for improvement, the domain of visual attention itself falls within the domain of perceptual processing of the cognitive model of driving and is associated with crash risk and thus warrants closer examination.

In light of these findings, it is important to examine the methodological improvements of the present study as a context in which to evaluate the current findings. Road tests are frequently considered the best measure of driving performance. Generally, the drawbacks are the inconsistency in administration and scoring, traffic density, number of evaluators, sampling period, and rating systems. All the aforementioned factors were addressed in the current study, except for controlling traffic density, despite attempts to pick low-traffic time periods. This study also involved a longer drive that involved realistic driving conditions and traffic patterns. Given an individual’s need for acclimation, eye-gaze sampling was only done for periods after significant acclimation to the vehicle and conditions. It is also important to consider that this study is the first in its kind to measure driving behavior after intervention in a purely objective measure such as eye gaze during an on-road drive. Thus, it is difficult to compare our findings with those of other studies. Past studies document significant reduction in dangerous maneuvers in a simulator as measured by a trained observer (Roenker, et al., 2003), increased a driver's probability of looking for a threat during a turn both in a simulator and on-road evaluation following active simulator training (Romoser & Fisher, 2009), and improved driving performance in a simulator following variable priority training (VPT; Cassavaugh & Kramer, 2009). However, the current research, which builds on many of the limitations of other studies, is also unique.

4.4 Limitations and Future Research

There are a number of theoretic and methodological limitations that may have influenced the findings in this study. The first relates to the sample. The current study may not be observing significant improvements in visual attention while driving because it is a relatively young, low-risk, cognitively intact sample. This was also a sample of individuals who have a computer and time availability that is necessary for completion of the study. Research has shown that declines in speed of processing, reasoning and memory have also been associated with increased rates of driving cessation (Anstey, Hofer, & Luczcz, 2003; K. Ball, et al., 2007; Edwards, et al., 2008); however, this is not relevant to the particular sample as they were cognitively intact.

The small sample size also impacted the statistics greatly. Given the small size, power was small, and the results are threatened by Type II error. Also, given the number of analyses run, the possibility of Type I error cannot be avoided and with a small sample size, Boneferonni corrections were not used. Another issue was that despite the lack of significant differences between groups on demographic and cognitive screening measures, the sample differed significantly at baseline for some of the neuropsychological measures and showed large standard deviations due to some participants' performances falling outside the normal curve. As a result differences due to intervention are more difficult to find statistically. Even with a smaller sample of those who completed the minimum 480 minutes of training, there was variation for some measures. A larger sample that would lend itself to matching baseline performances may tease out improvement purely from intervention better.

The trend towards changes between visits for the waitlist control group, both for some neuropsychological and eye gaze measures, may be evidence of practice effects. For example, UFOV measures showed the most robust changes. It should be noted that this test is akin to the DriveSharp™'s Road Tour training except not as visually pleasing. This brings into question whether individuals are training a cognitive construct or simply improving performance on a game through practice. While the addition of a waitlist control group was made in an attempt to elucidate some of the practice tests, it is difficult to determine the effectiveness of the intervention for some measures due to a small sample size and the waitlist control group undergoing 3 visits in contrast to the 2 visits of the intervention group. This design was able to identify the impact that practice effects may have on outcome measures, which other studies fail to address (Cassavaugh & Kramer, 2009; Roenker, et al., 2003; Seidler, et al., 2010).

Perhaps, most importantly, is that eye gaze is not a direct measure of driving performance such as acceleration or lane maintenance may be. While eye gaze is a more finite and objective measure it is not a direction relationship with driving performance. The present study was run in conjunction with a larger study in a fully instrumented vehicle and thus has this information available; however, it was outside the scope of the aims here. Added difficulty in making statements about ecological validity as it relates to driving is that the occurrences of dangerous maneuvers are rare behaviors, particularly when the observer-examiner effect is at play such as in a study like this. The phenomenon that cognitive changes are observed sooner than functional change may be influencing driving performance as well. It may be that the eye gaze changes we are observing, with

practice, would lead to functional changes in driving performance. However, without a follow-up driving evaluation it would be difficult to elucidate this.

Future research should first provide a more consistent way of tracking time spent using the training program so as to ensure the minimum amount of training is completed. More importantly, in terms of the driving evaluation, it would be beneficial to more closely examine whether individuals are processing information in their useful field of view during driving. The challenge, however, comes in developing a means of measuring this that in conjunction ensures safe driving. As mentioned above, data that are available and not yet analyzed, will aim to determine whether there are differences in driving performance as measured by vehicle speed, braking, etc or physiology after intervention. With a larger sample size and one that completed the minimum training, further analyses can delineate improvements and what aspect of the training predicts improvement in visual allocation on the road. For example, does better performance on Jewel Diver hold more of the variance in performance changes with intervention? Which neuropsychological measure best predicts improvement in visual allocation on the road? While there are a number of areas to build and grown on from this study, the results pave the way for gaining a better understanding of how training can impact more functional measures of visual attention.

4.5 Implications of Study

This study begins the path to future research, in promoting cognitive health as Hendrie et al. (2006) defined it as well as beginning to identify the effectiveness of cognitive training. Presently, the implications of a brief cognitive training impacting driving performance in a normal aging are paramount. It appears as though targeted

visual attention training can improve one's visual attention thus supporting theories around new learning in aging, specifically those around speed of processing. Also, if the improvements observed in eye gaze map onto real time driving improvement, the implications for older driver independence and social policy may change. Older drivers staying on the road safely lessens emotional and financial strain on the individuals and their families. It allows for social connectedness and facilitates medical care for those that like in more suburban and rural areas. As of now, older drivers are scrutinized. States threaten with laws that would take away licenses from older individuals after a certain age. This study may provide hope that older drivers can improve their on-road attention and thereby maintain independence. Also, if cognitively intact older driver are improving on a task that was normally only thought to help those who are showing deficits, the population able to be helped increases tremendously. In the same vein, perhaps individuals with attentional deficits of all ages who are at crash risk can benefit from training.

If visual attention training improves the UFOV of those multitasking with another visual task, drivers may be safer on the road and it could lead to more improvements in the technology offered in vehicles. For example, given the visual component of the dashboard or navigations systems, this may improve a driver's ability to use these instruments and to react in time during times of multitasking. Future innovations in vehicles can utilize this information to better adapt to drivers, particularly in areas that are amenable to training.

4.6 Conclusion

This is the first waitlist-controlled trial of the DriveSharp™ software using an on-road assessment with objective measures of performance. I was unable to show definitive improvements across neuropsychological and driving measures; however, there is reason to believe that a larger sample with the minimum of 480 minutes of training may provide more promising results. There is potential for improvement in ecological transfer tasks such as driving, however, without knowing some of the mechanisms to better design and evaluate driving behavior, researchers may fall into similar patterns of results.

APPENDIX A

SCREENING QUESTIONNAIRE

1.	Are you Male or Female?	☐Male ☐Female
2.	Are you between the ages of 60 and 75?	☐ Yes ☐ No
3.	What is your date of birth?	__ __/__ __/__ __ __ __ M M D D Y Y Y Y
4.	Have you had your driver's license for over three years?	☐ Yes ☐ No
5.	Do you drive more than three times a week?	☐ Yes ☐ No
6	Are you comfortable driving a mid-sized sedan such as a Ford Taurus?	☐ Yes ☐ No
7.	Are you in good health?	☐ Yes ☐ No
8.	Do you understand and speak English?	☐ Yes ☐ No
9.	Do you have a social security number and agree to provide it to MIT to obtain compensation?	☐ Yes ☐ No
10	Have you been the driver in a police reported accident in the past year?	☐ Yes ☐ No
11.	Have you had a medical condition resulting in **any** hospitalization within the past 6 months?	☐ Yes ☐ No
12.	Do you wear glasses to drive?	☐ Yes ☐ No
13.	Do you wear contacts to drive?	☐ Yes ☐ No
14.	Can you commit to two daily sessions of 30 minutes for the computer training program?	☐ Yes ☐ No
15.	Do you have a computer? Is it a PC or Mac? Check if it meets these requirements. **Min Req for Windows** Windows 2000, XP Home or Professional, Vista, Windows 7 At least 256MB RAM (512MB for Vista) 1GHz or faster processor X24 CD-ROM or DVD drive 500MB free disk space Headphone jack **Min Req for Mac** Power PC 10.3.9 – 10.4.x Intel 10.4.x – 10.6.x At least 512MB RAM Combo Drive/DVD 1GB free disk space Headphone jack	☐ Yes ☐ No
16.	Do you have any neurological problems?	☐ Yes ☐ No
17.	Do you have internet access?	☐ Yes ☐ No

18.	Are you currently being treated for a mental disorder?	☐ Yes	☐ No
19.	Do you have a pacemaker?	☐ Yes	☐ No

There are a few medications that I need to ask you about. Have you used any of the following in the past 12 months?

20.	Anti-convulsant medication?	☐ Yes	☐ No
21.	Immunosuppressive drugs or cytotoxic drugs?	☐ Yes	☐ No
22.	Anti-depressant medication?	☐ Yes	☐ No
23.	Anti-psychotic medication?	☐ Yes	☐ No
24.	Anti-anxiety medication?	☐ Yes	☐ No
25.	Medications to treat a major medical condition such as cancer?	☐ Yes	☐ No
26.	In the past two days, have you used any medications that made you drowsy?	☐ Yes	☐ No

Health Information

Note: Answering "Yes" to any of the following questions will not exclude you from participating in the study. Have you ever had any of the following (check all that apply):

- ☐ Heart Attack
- ☐ Angina
- ☐ Heart Failure
- ☐ Coronary Artery Bypass Grafting
- ☐ Angioplasty
- ☐ Diabetes
- ☐ Stroke
- ☐ Transient Ischemic Attach (TIA)
- ☐ Kidney disease or renal failure
- ☐ Endocrinopathy
- ☐ Coronary Heart Disease
- ☐ Cushing's Disease

☐ A medical diagnosis of high blood pressure:

If you checked the box above, are you taking medications for the treatment of high blood pressure?

☐ Yes ☐ No

If you said yes to the above question, what is the name of the medication?

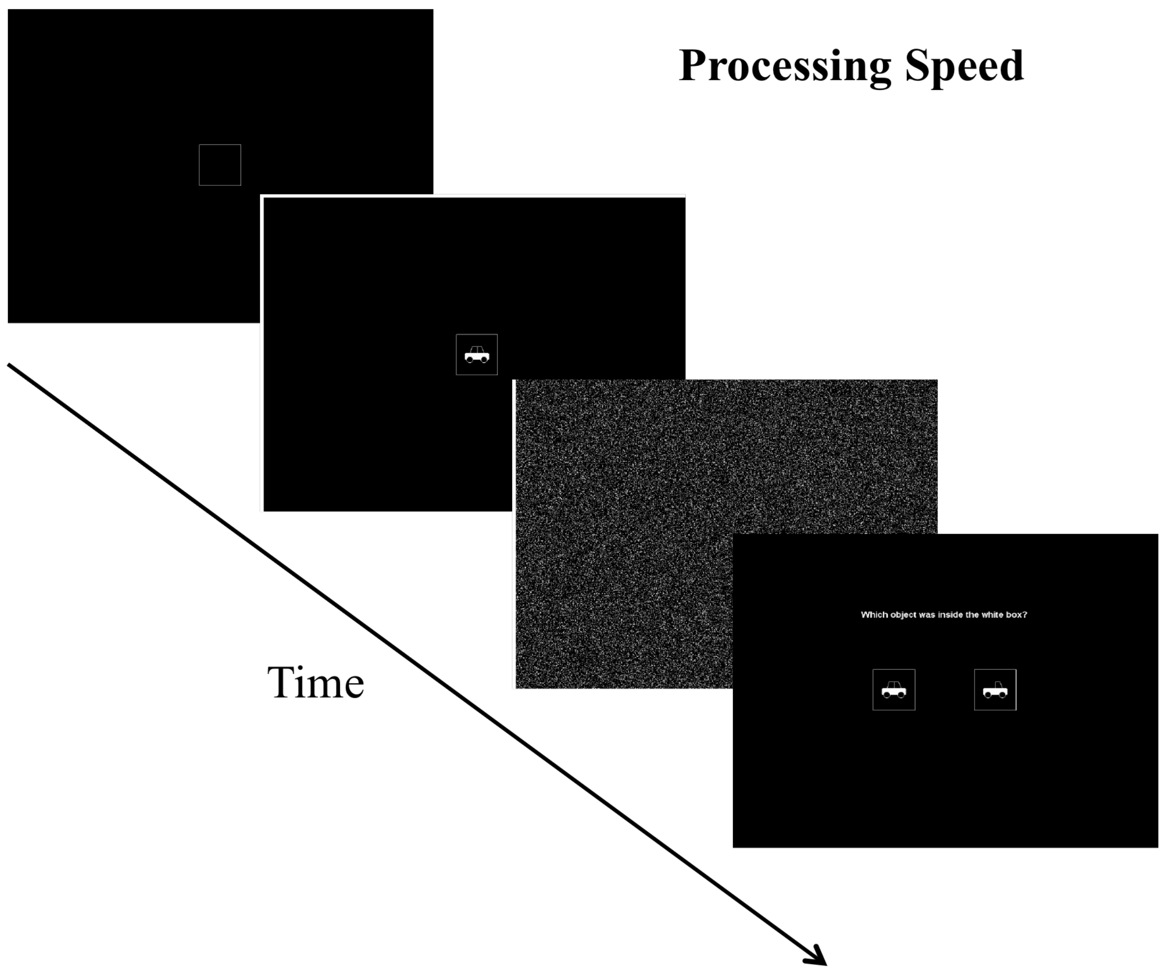
APPENDIX B

RANDOMIZATION CHART

Subject #	Treatment Arm	Day 0						Day 1					Day 2				
		RBANS	Trails	Matrix	ANT	UFOV	Driving	Trails	Matrix	ANT	UFOV	Driving	Trails	Matrix	ANT	UFOV	Driving
1	Intervention	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	×	×	×	×	×
2	Wait-List	✓	×	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓
3	Intervention	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	×	×	×	×	×
4	Wait-List	✓	×	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓
5	Intervention	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	×	×	×	×	×
6	Wait-List	✓	×	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓
7	Intervention	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	×	×	×	×	×
8	Wait-List	✓	×	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓
9	Intervention	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	×	×	×	×	×
10	Wait-List	✓	×	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓
11	Intervention	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	×	×	×	×	×
12	Wait-List	✓	×	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓
13	Intervention	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	×	×	×	×	×
14	Wait-List	✓	×	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓
15	Intervention	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	×	×	×	×	×
16	Wait-List	✓	×	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓
17	Intervention	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	×	×	×	×	×
18	Wait-List	✓	×	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓
19	Intervention	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	×	×	×	×	×
20	Wait-List	✓	×	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓
21	Intervention	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	×	×	×	×	×
22	Wait-List	✓	×	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓
23	Intervention	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	×	×	×	×	×
24	Wait-List	✓	×	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓
25	Intervention	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	×	×	×	×	×
26	Intervention	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	×	×	×	×	×
27	Intervention	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	×	×	×	×	×
28	Wait-List	✓	×	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓
29	Intervention	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	×	×	×	×	×
30	Wait-List	✓	×	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓
31	Intervention	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	×	×	×	×	×
32	Wait-List	✓	×	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓
33	Intervention	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓	×	×	×	×	×
34	Wait-List	✓	×	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓
35	Intervention	✓	A/B	Ravens A	✓	✓	✓	C/D	Ravens B	✓	✓	✓	×	×	×	×	×
36	Wait-List	✓	×	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓
37	Intervention	✓	C/D	Ravens B	✓	✓	✓	A/B	Ravens C	✓	✓	✓	×	×	×	×	×
38	Wait-List	✓	×	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓
39	Intervention	✓	A/B	Ravens C	✓	✓	✓	C/D	Ravens A	✓	✓	✓	×	×	×	×	×
40	Wait-List	✓	×	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓
41	Intervention	✓	C/D	Ravens A	✓	✓	✓	A/B	Ravens B	✓	✓	✓	×	×	×	×	×
42	Wait-List	✓	×	Ravens B	✓	✓	✓	C/D	Ravens C	✓	✓	✓	A/B	Ravens A	✓	✓	✓

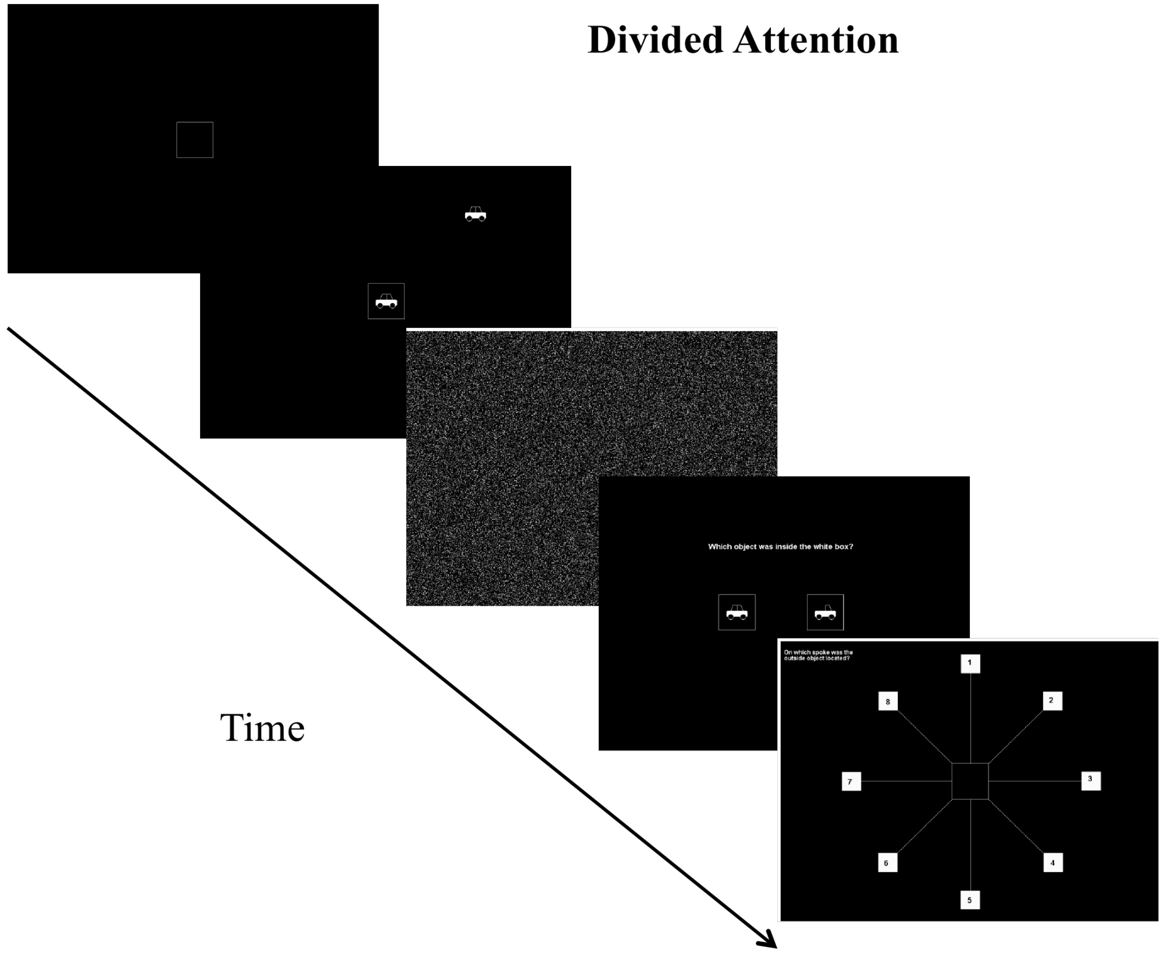
APPENDIX C

USEFUL FIELD OF VIEW (UFOV) SCREENS

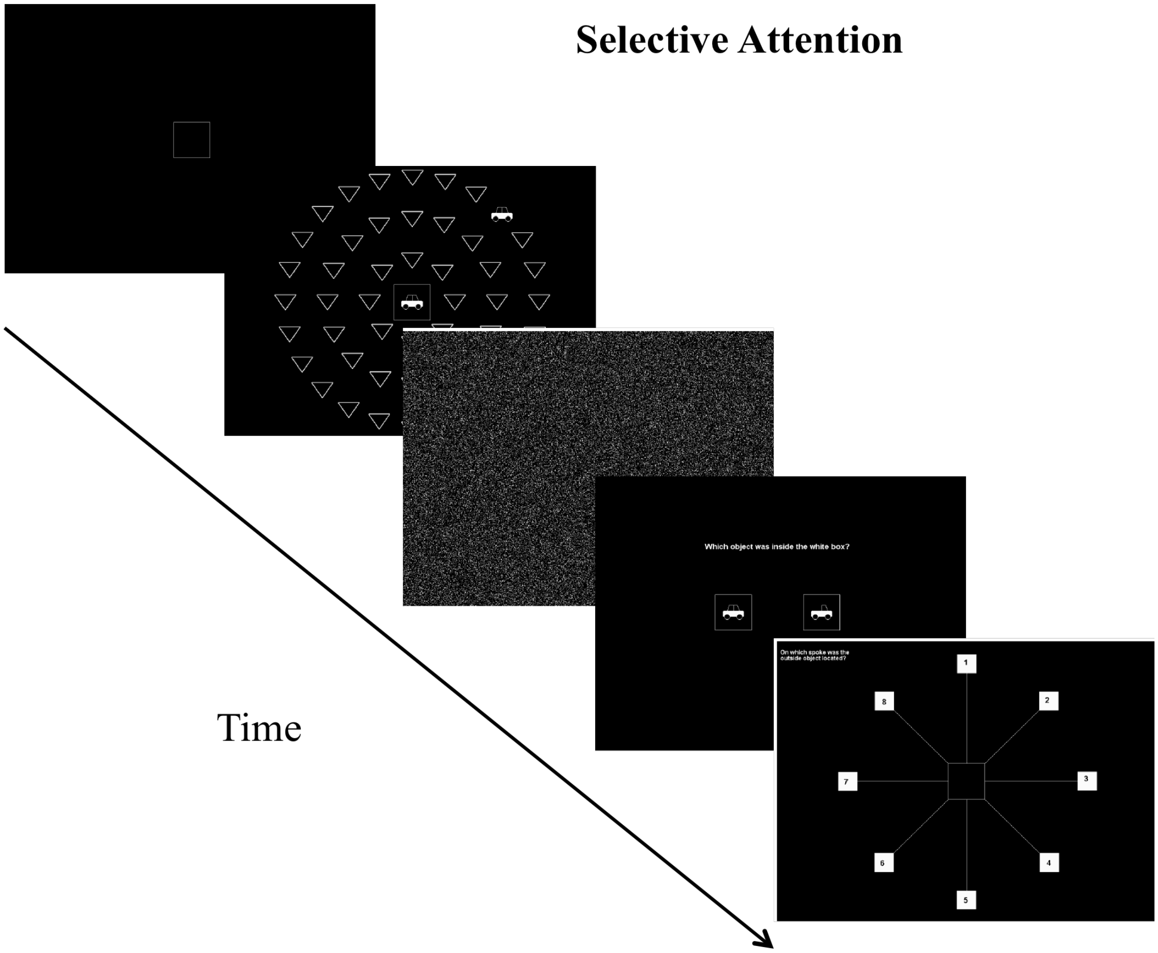


USEFUL FIELD OF VIEW (UFOV) SCREENS (CONTINUED)

Divided Attention

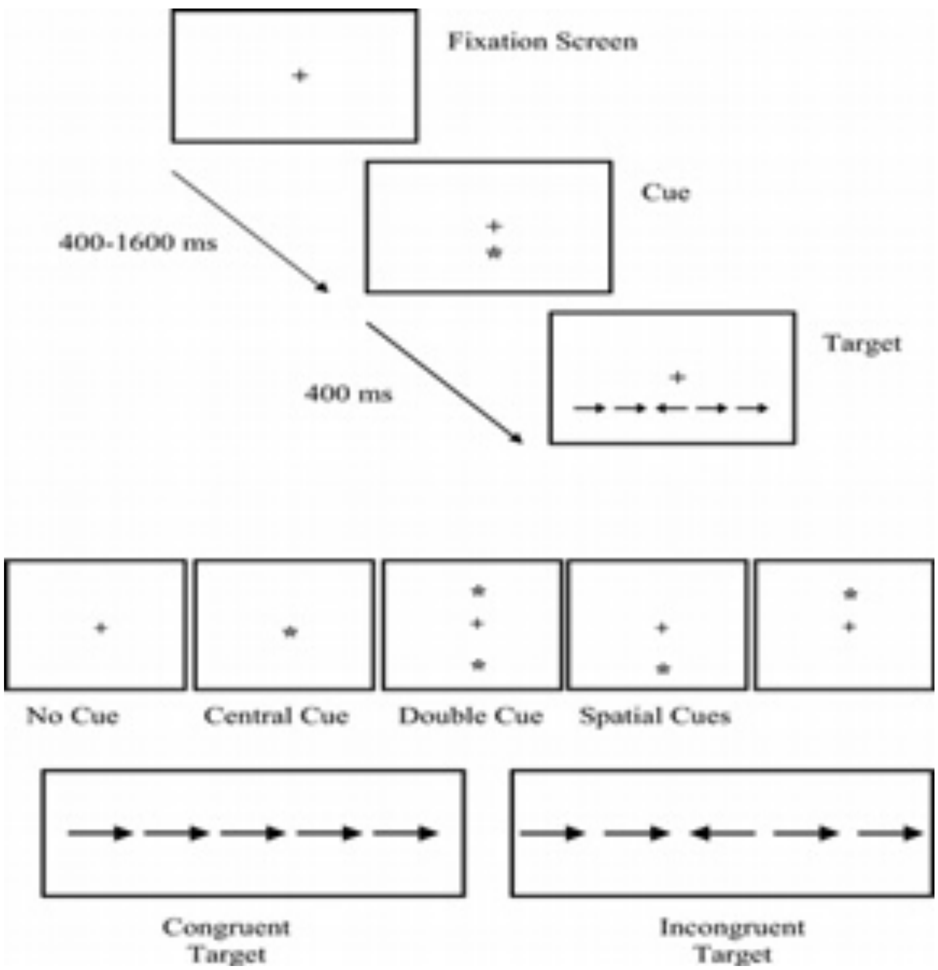


USEFUL FIELD OF VIEW (UFOV) SCREENS (CONTINUED)



APPENDIX D

ATTENTION NETWORK TEST (ANT) SCREENS



Courtesy of
http://www.glyndwr.ac.uk/en/UniversityInstitutes/UniversityInstituteforHealthMedicalSciencesandSociety/Psychology/Facilities/Experimentalcubicles/ImageUpload,17629,en.jpg

APPENDIX E

PHOTOS OF THE MIT AGELAB INSTRUMENTED VEHICLE

(a) Camera and eye-tracking set-up

(b) computer controls in rear of vehicle

(c) Driver console

(d) 2010 Lincoln MKS in parking lot

APPENDIX F

TABLES OF OBSERVED AND DERIVED DATA

Table 1. Demographic information and baseline cognitive profile (mean standard score on RBANS) for participants assigned to Waitlist Control versus DriveSharp™ conditions

	Waitlist Control N = 16	DriveSharp™ N = 16	*p*-value
Age	66.31 (5.83)	66.81 (4.55)	0.374
% female	44%	50%	0.723
% White	94%	88%	0.219
% Right Handed	88%	88%	0.513
Years of education	16.38 (2.78)	17.93 (2.40)	0.313
RBANS Total Score	103.94 (11.35)	104.50 (15.89)	0.390
RBANS Immediate Memory	97.81 (12.91)	101.27 (10.77)	0.287
RBANS Visuospatial	105.75 (17.86)	107.13 (16.00)	0.222
RBANS Language	97.94 (10.34)	103.25 (12.88)	0.369
RBANS Attention	111.63 (15.87)	107.75 (16.26)	0.539
RBANS Delayed Memory	102.56 (10.83)	104.00 (12.42)	0.730

Table 2. Comparison of performance on time to completion (seconds) and standardized z-scores for the Trailmaking task between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**Time to Completion** *(n = 32)*		**Significant Results**	**Z-scores** *(n = 32)*		**Significant Results**
	Pre	Post		Pre	Post	
Trailmaking A/C	36.63 (13.99)	32.19 (10.2)	c	0.16 (1.00)	0.45 (0.84)	c
Trailmaking B/D	87.83 (37.18)	87.01 (43.33)		0.06 (0.86)	0.35 (0.97)	
TRAINING ≥ 480 MINUTES	**Time to Completion** *(n = 17)*		**Significant Results**	**Z-scores** *(n = 17)*		**Significant Results**
	Pre	Post		Pre	Post	
Trailmaking A/C	36.53 (14.81)	31.05 (9.52)		0.18 (0.94)	0.51 (0.79)	
Trailmaking B/D	85.07 (43.85)	78.59 (32.35)		0.10 (1.06)	0.26 (0.68)	

c = Combined group significant ($p \leq 0.05$) c° = Combined group large effect size ($d \geq 0.14$)

Table 3. Comparison of performance on the UFOV test between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	DriveSharp™ (n = 16)		Waitlist Control (n = 16)		Combined (n = 32)		Significant Results
	Pre	Post	Pre	Post	Pre	Post	
Processing Speed (msec)	30.00 (36.87)	16.70 (0.00)	24.81 (19.41)	17.33 (2.50)	27.41 (29.10)	17.01 (1.77)	b°, c
Divided Attention (msec)	113.57 (106.8)	31.26 (30.93)	46.08 (43.28)	20.88 (10.67)	79.82 (87.17)	43.05 (75.72)	a, a°
Selected Attention (msec)	132.13 (67.64)	82.93 (46.69)	96.11 (47.03)	66.70 (28.86)	114.12 (60.16)	95.22 (85.42)	a, a°, c
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Processing Speed (msec)	23.03 (18.89)	16.70 (0.00)	20.50 (10.05)	16.70 (0.00)	21.99 (15.50)	16.70 (0.00)	b°, c°
Divided Attention (msec)	88.70 (98.36)	28.34 (30.47)	40.53 (37.25)	22.43 (15.16)	68.86 (80.99)	35.11 (50.77)	a, a°, b°, c°
Selected Attention (msec)	111.39 (55.12)	68.69 (43.52)	94.80 (30.50)	61.44 (29.20)	104.56 (46.14)	73.55 (38.21)	a, a°, b°, c, c°

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)

a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 4. Comparison of performance on the ANT task between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**DriveSharp™** *(n = 16)*		**Waitlist Control** *(n = 16)*		**Combined** *(n = 32)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Conflict Reaction Time (mesc)	128.88 (55.45)	99.10 (43.47)	136.93 (74.36)	101.77 (32.08)	132.90 (64.65)	1004.4 2 (37.61)	a, a°, b°, c, c°
Average Reaction Time (mesc)	728.52 (95.93)	676.48 (91.75)	723.36 (115.9)	672.06 (103.2)	7265.94 (104.7)	685.30((99.01)	a, a°, b, b°, c, c°
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Conflict Reaction Time (mesc)	121.58 (56.25)	93.16 (45.84)	147.37 (103.9)	86.37 (32.38)	132.30 (77.43)	92.99 (41.82)	a, a°, b°, c°
Average Reaction Time (mesc)	705.77 (87.84)	648.77 (74.16)	703.29 (139.3)	666.85 (115.5)	704.75 (107.80)	661.05 (96.10)	a, a°, b°, c, c°

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)
a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 5. Comparisons of performance on neuropsychological test measures across 3 visits for the waitlist control group in the total sample, Mean (SD).

(*n = 16*)	**Visit 1**	**Visit 2**	**Visit 3**	**Significant Results**
***UFOV** (msec)*				
Processing Speed	24.81 (19.40)	17.33 (2.50)	17.33 (2.50)	
Divided Attention	46.08 (43.28)	54.84 (102.9)	20.88 (10.67)	c
Selective Attention	96.11 (47.03)	107.52 (112.2)	66.70 (28.86)	c
***ANT** (msec)*				
Conflict Reaction Time	136.93 (74.36)	101.77 (32.08)	91.19 (27.77)	c
Average Reaction Time	723.36 (115.93)	694.12 (108.1)	672.06 (103.16)	c

a = Visit 1 significantly different from Visit 2 ($p \leq 0.05$)
b = Visit 2 significantly different from Visit 3 ($p \leq 0.05$)
c = Visit 1 significantly different from Visit 3 ($p \leq 0.05$)

Table 6. Comparison of standard deviation of horizontal eye gaze during an auditory working memory task while driving between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**DriveSharp™** *(n = 16)*		**Waitlist Control** *(n = 16)*		**Combined** *(n = 32)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre 1-Back Task	0.10 (0.03)	0.09 (0.03)	0.12 (0.04)	0.12 (0.05)	0.11 (0.04)	0.08 (0.03)	
During 1-Back Task	0.08 (0.04)	0.09 (0.06)	0.08 (0.03)	0.09 (0.05)	0.08 (0.03)	0.08 (0.04)	
Post 1-Back Task	0.09 (0.03)	0.10 (0.04)	0.12 (0.05)	0.12 (0.05)	0.11 (0.04)	0.09 (0.04)	
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre 1-Back Task	0.09 (0.03)	0.09 (0.02)	0.13 (0.03)	0.12 (0.06)	0.10 (0.03)	0.12 (0.03)	b°, c°
During 1-Back Task	0.09 (0.04)	0.08 (0.06)	0.08 (0.02)	0.08 (0.03)	0.07 (0.03)	0.010 (0.05)	
Post 1-Back Task	0.09 (0.03)	0.09 (0.03)	0.13 (0.03)	0.12 (0.02)	0.11 (0.04)	0.11 (0.04)	

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)

a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 7. Comparison of standard deviation of vertical eye gaze during an auditory working memory task while driving between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**DriveSharp™** *(n = 16)*		**Waitlist Control** *(n = 16)*		**Combined** *(n = 32)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre 1-Back Task	0.06 (0.02)	0.09 (0.03)	0.05 (0.02)	0.07 (0.03)	0.06 (0.02)	0.06 (0.03)	
During 1-Back Task	0.06 (0.03)	0.09 (0.06)	0.06 (0.02)	0.07 (0.02)	0.06 (0.02)	0.06 (0.02)	
Post 1-Back Task	0.06 (0.02)	0.11 (0.04)	0.06 (0.02)	0.07 (0.03)	0.06 (0.02)	0.07 (0.03)	b°
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre 1-Back Task	0.06 (0.02)	0.05 (0.01)	0.06 (0.02)	0.07 (0.03)	0.06 (0.02)	0.06 (0.02)	
During 1-Back Task	0.05 (0.02)	0.06 (0.02)	0.07 (0.03)	0.06 (0.02)	0.06 (0.02)	0.06 (0.03)	
Post 1-Back Task	0.06 (0.030	0.06 (0.02)	0.05 (0.01)	0.07 (0.03)	0.05 (0.02)	0.07 (0.03)	b°

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)

a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 8. Comparison of standard deviation of horizontal eye gaze during a visual working memory task while driving between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**DriveSharp™** *(n = 16)*		**Waitlist Control** *(n = 16)*		**Combined** *(n = 32)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre Clock Task	0.09 (0.03)	0.11 (0.03)	0.11 (0.04)	0.12 (0.05)	0.10 (0.04)	0.09 (0.04)	a, a°, c, c°
During Clock Task	0.08 (0.03)	0.08 (0.03)	0.08 (0.04)	0.10 (0.04)	0.08 (0.03)	0.07 (0.03)	b°
Post Clock Task	0.11 (0.03)	0.10 (0.02)	0.11 (0.04)	0.13 (0.04)	0.11 (0.03)	0.08 (0.03)	b°
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre Clock Task	0.09 (0.04)	0.11 (0.03)	0.12 (0.03)	0.11 (0.06)	0.10 (0.03)	0.12 (0.03)	a, a°
During Clock Task	0.07 (0.04)	0.08 (0.04)	0.07 (0.02)	0.10 (0.04)	0.07 (0.03)	0.10 (0.05)	
Post Clock Task	0.10 (0.03)	0.10 (0.02)	0.13 (0.04)	0.12 (0.04)	0.11 (0.04)	0.11 (0.03)	

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)

a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 9. Comparison of standard deviation of vertical eye gaze during a visual working memory task while driving between pre- and post-intervention with DriveSharp™, Mean (SD).

TOTAL SAMPLE	**DriveSharp™** *(n = 16)*		**Waitlist Control** *(n = 16)*		**Combined** *(n = 32)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre Clock Task	0.05 (0.02)	0.05 (0.01)	0.06 (0.03)	0.06 (0.02)	0.05 (0.02)	0.06 (0.02)	b, b°
During Clock Task	0.05 (0.02)	0.06 (0.02)	0.05 (0.02)	0.06 (0.03)	0.05 (0.02)	0.06 (0.03)	
Post Clock Task	0.06 (0.02)	0.06 (0.02)	0.06 (0.030	0.06 (0.02)	0.06 (0.02)	0.06 (0.02)	
TRAINING ≥ 480 MINUTES	**DriveSharp™** *(n = 10)*		**Waitlist Control** *(n = 7)*		**Combined** *(n = 17)*		**Significant Results**
	Pre	Post	Pre	Post	Pre	Post	
Pre Clock Task	0.05 (0.02)	0.05 (0.01)	0.06 (0.03)	0.06 (0.02)	0.05 (0.03)	0.06 (0.02)	
During Clock Task	0.06 (0.02)	0.06 (0.02)	0.05 (0.01)	0.07 (0.04)	0.06 (0.02)	0.06 (0.03)	
Post Clock Task	0.06 (0.02)	0.06 (0.02)	0.07 (0.02)	0.06 (0.03)	0.06 (0.02)	0.07 (0.03)	

a = DriveSharp™ group significant ($p \leq 0.05$)
b = Waitlist group significant ($p \leq 0.05$)
c = Combined group significant ($p \leq 0.05$)

a° = DriveSharp™ group large effect size ($d \geq 0.14$)
b° = Waitlist Control group large effect size ($d \geq 0.14$)
c° = Combined group large effect size ($d \geq 0.14$)

Table 10. Comparisons of standard deviations of eye-gaze during the on-road drive across visits for the waitlist control group, Mean (SD).

Auditory Working Memory Task				
(*n = 16)*	**Visit 1**	**Visit 2**	**Visit 3**	**Significant Results**
Horizontal				
Pre 1-Back Task	0.12 (0.04)	0.13 (0.04)	0.12 (0.05)	
During 1-Back Task	0.08 (0.03)	0.10 (0.05)	0.09 (0.04)	
Post 1-Back Task	0.12 (0.05)	0.12 (0.04)	0.12 (0.05)	
Vertical				
Pre 1-Back Task	0.06 (0.02)	0.07 (0.05)	0.07 (0.03)	
During 1-Back Task	0.07 (0.05)	0.07 (0.04)	0.07 (0.02)	
Post 1-Back Task	0.06 (0.02)	0.08 (0.04)	0.07 (0.03)	
Visual Working Memory Task				
(*n = 16)*	**Visit 1**	**Visit 2**	**Visit 3**	**Significant Results**
Horizontal				
Pre 1-Back Task	0.11 (0.04)	0.13 (0.04)	0.12 (0.05)	
During 1-Back Task	0.08 (0.04)	0.10 (0.05)	0.10 (0.04)	
Post 1-Back Task	0.11 (0.04)	0.13 (0.04)	0.13 (0.04)	
Vertical				
Pre 1-Back Task	0.06 (0.03)	0.07 (0.04)	0.06 (0.02)	
During 1-Back Task	0.05 (0.02)	0.06 (0.04)	0.06 (0.03)	
Post 1-Back Task	0.06 (0.03)	0.07 (0.04)	0.06 (0.02)	

a = Visit 1 significantly different from Visit 2 ($p \leq 0.05$)
b = Visit 2 significantly different from Visit 3 ($p \leq 0.05$)
c = Visit 1 significantly different from Visit 3 ($p \leq 0.05$)

Table 11. Comparison of accuracy in completion of working memory tasks during on-road driving between visit 1 and visit 2, Mean (SD).

Total Sample	**DriveSharp™**		**Control**	
	Visit 1	Visit 2	Visit 1	Visit 2
Auditory (1-Back; % Correct)	0.92 (0.09)	0.93 (0.14)	0.97 (0.05)	0.93 (0.18)
Visual (Clock; % Correct)	0.89 (0.14)	0.96 (0.07)	0.88 (0.15)	0.90 (0.16)

Training ≥ 480 min	**DriveSharp™**		**Control**	
	Visit 1	Visit 2	Visit 1	Visit 2
Auditory (1-Back; % Correct)	0.92 (0.09)	0.98 (0.06)	0.98 (0.03)	0.89 (0.26)
Visual (Clock; % Correct)	0.88 (0.17)	0.92 (0.17)	0.89 (0.16)	0.96 (0.07)

* denotes significance (p-value ≤ 0.05)

APPENDIX G

FIGURES OF OBSERVED AND DERIVED DATA

Figure 1. Flow chart for study enrollment.

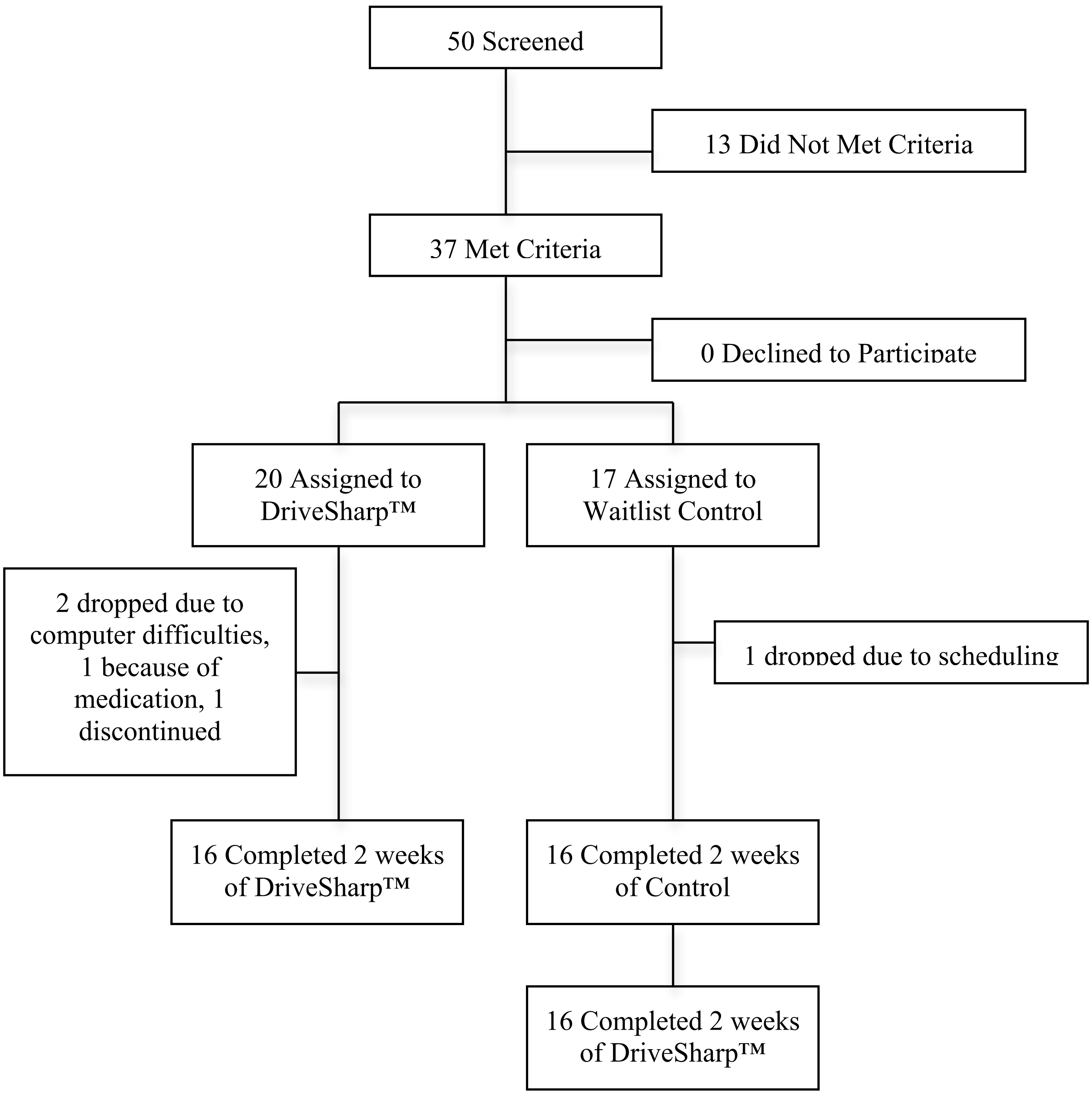


Figure 2. Procedure Flowchart.

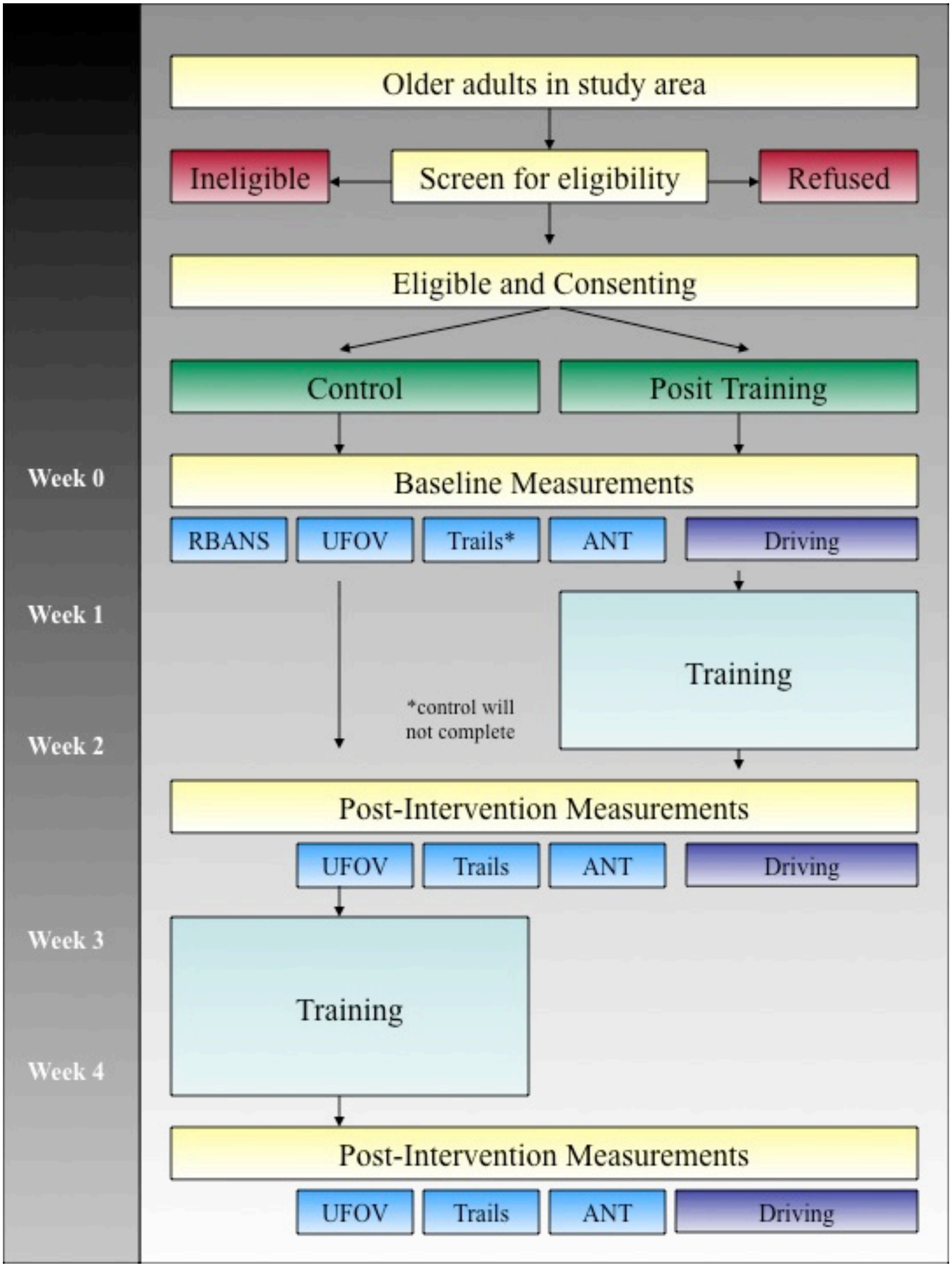
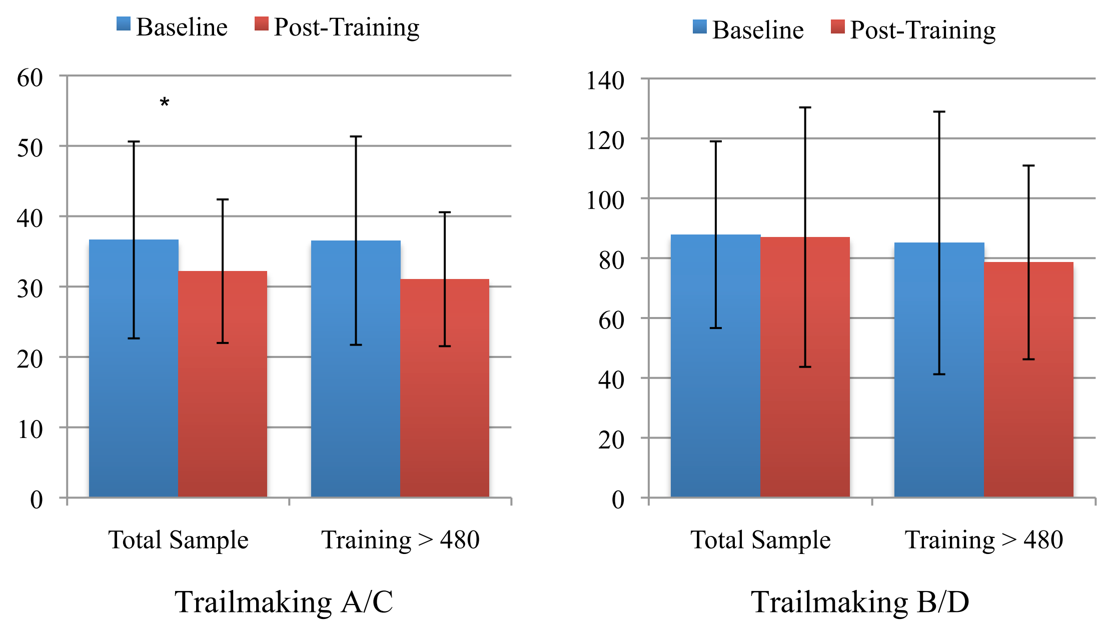
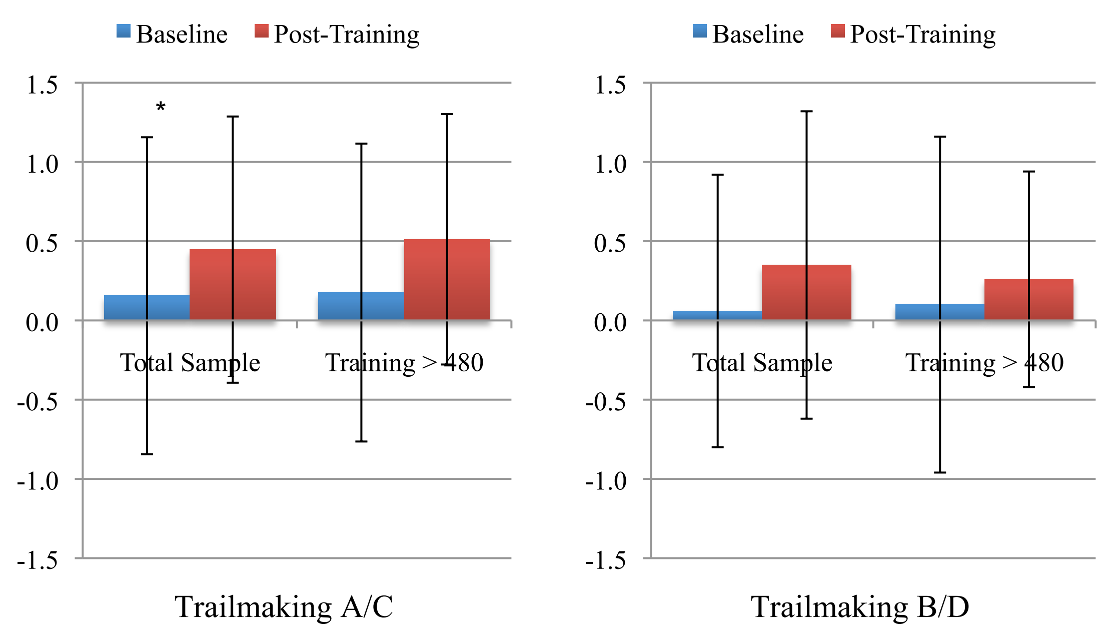


Figure 3. Performance on Trailmaking at Baseline and Post-Training with DriveSharp™

Trailmaking (Time to Completion in seconds)



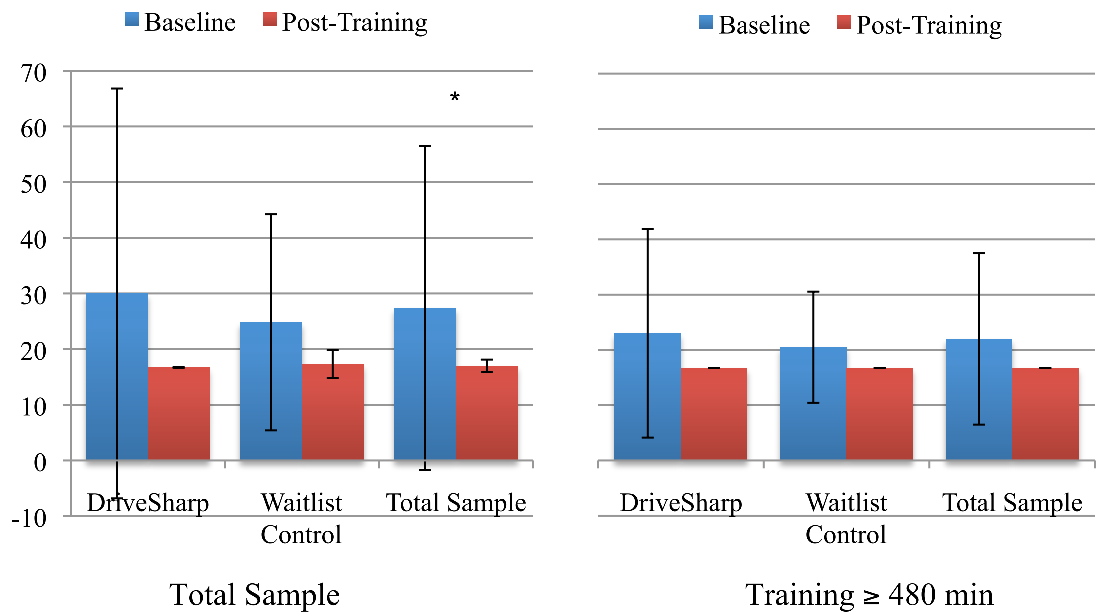
Trailmaking (z-scores)



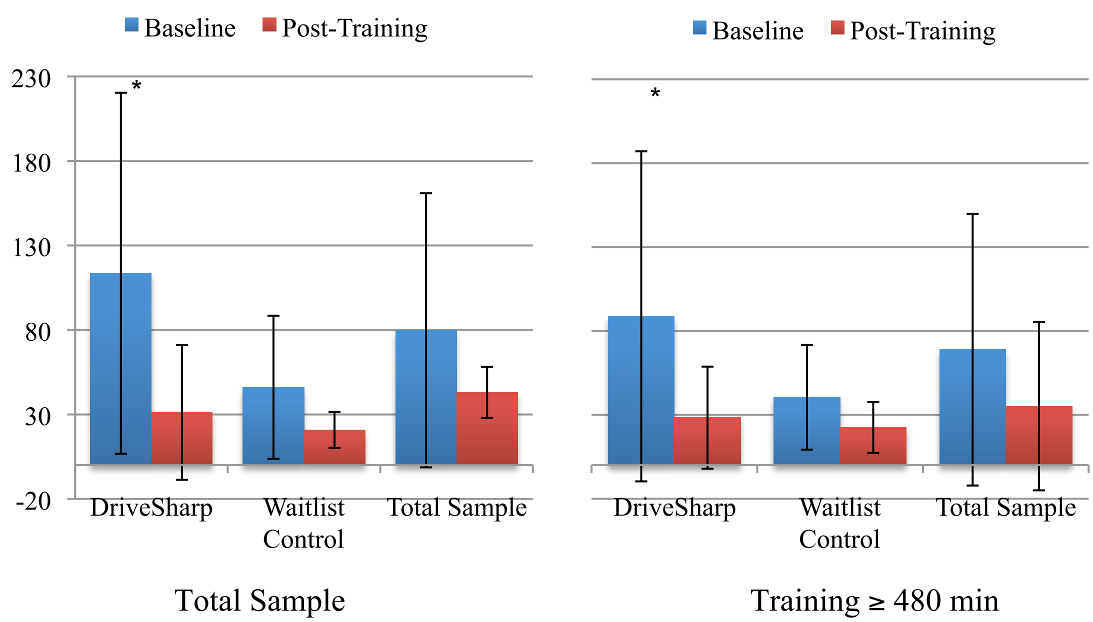
* denotes significance (p-value ≤ 0.05)

Figure 4. Performance on UFOV at Baseline and Post-Training with DriveSharp™

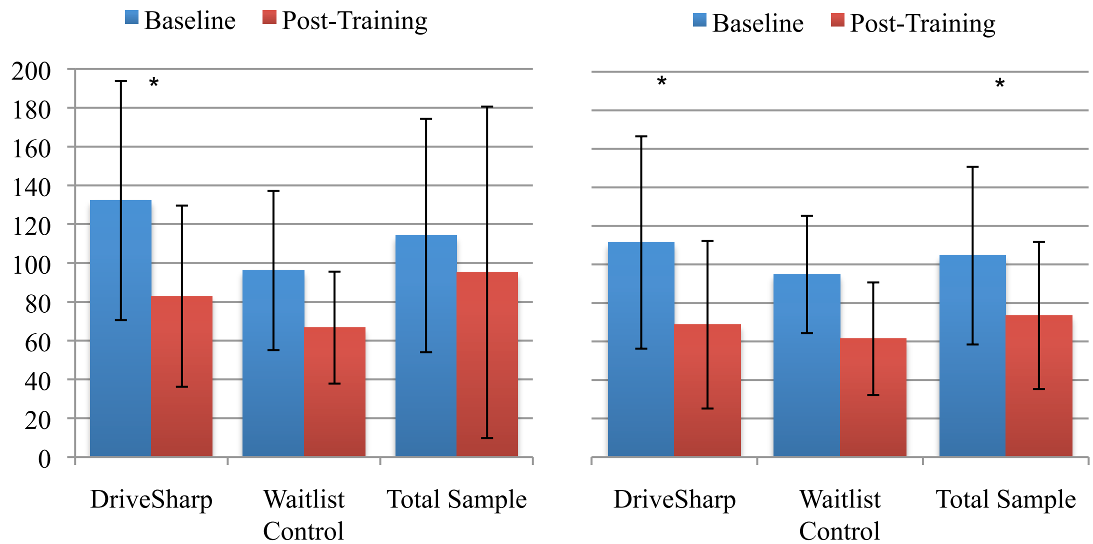
<u>Processing Speed (msec)</u>



<u>Divided Attention (msec)</u>



<u>Selected Attention (msec)</u>



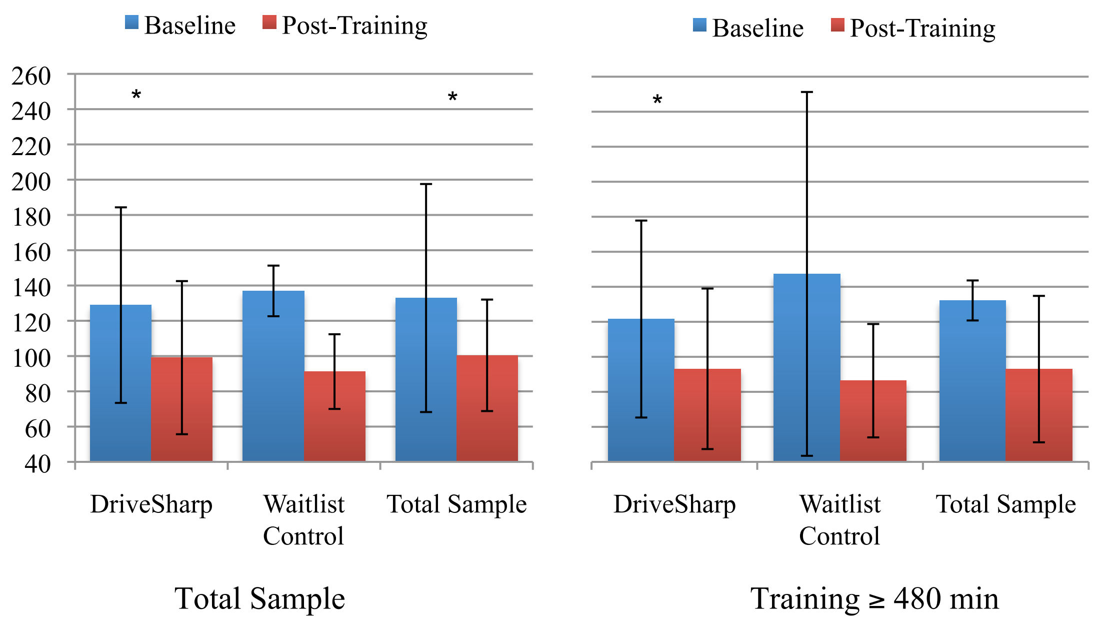
Total Sample

Training ≥ 480 min

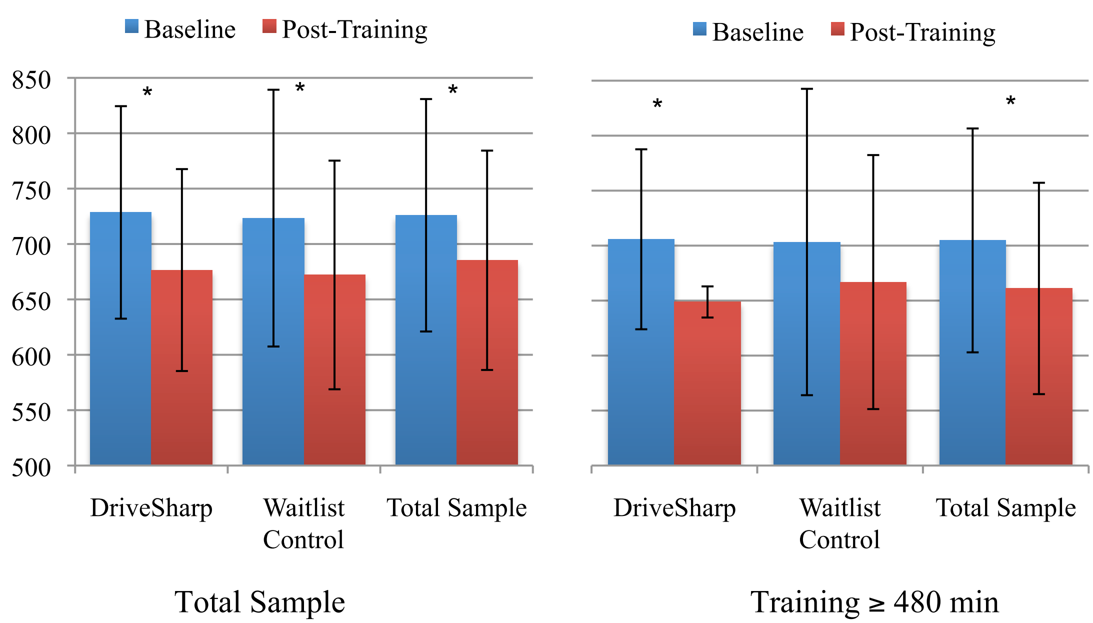
* denotes significance (p-value ≤ 0.05)

Figure 5. Performance on ANT at Baseline and Post-Training with DriveSharp™

Conflict (msec)

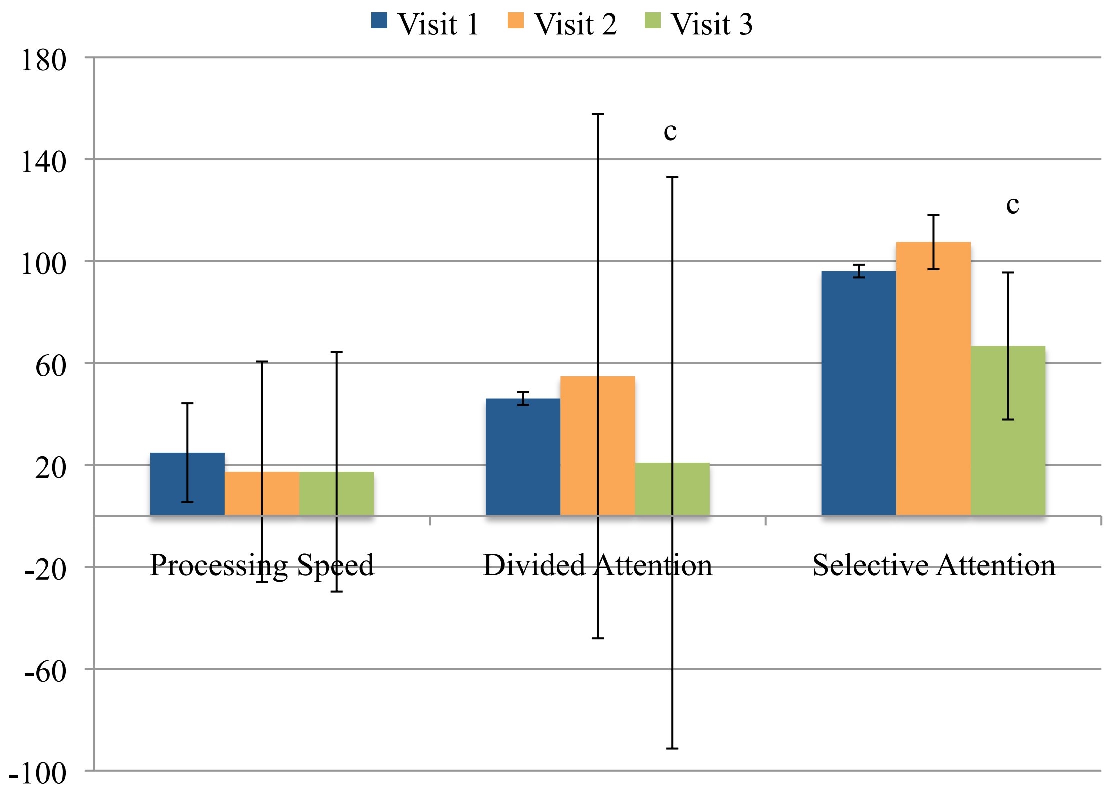


Average Reaction Time (msec)



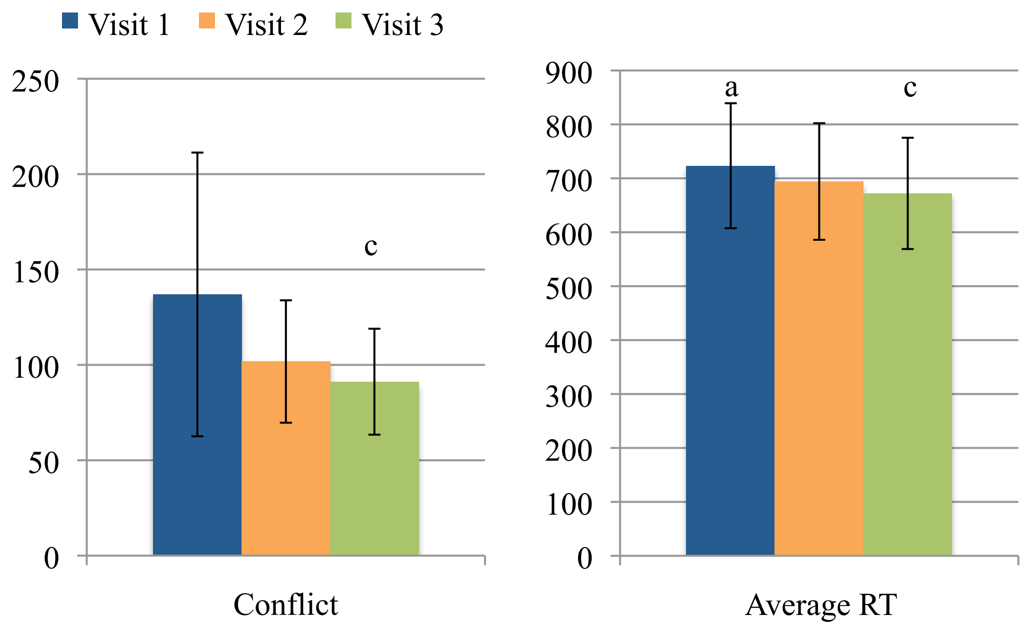
* denotes significance (p-value ≤ 0.05)

Figure 6. Waitlist control performance across 3 visits for UFOV.



a = Visit 1 significantly different from Visit 2 ($p \leq 0.05$)
b = Visit 2 significantly different from Visit 3 ($p \leq 0.05$)
c = Visit 1 significantly different from Visit 3 ($p \leq 0.05$)

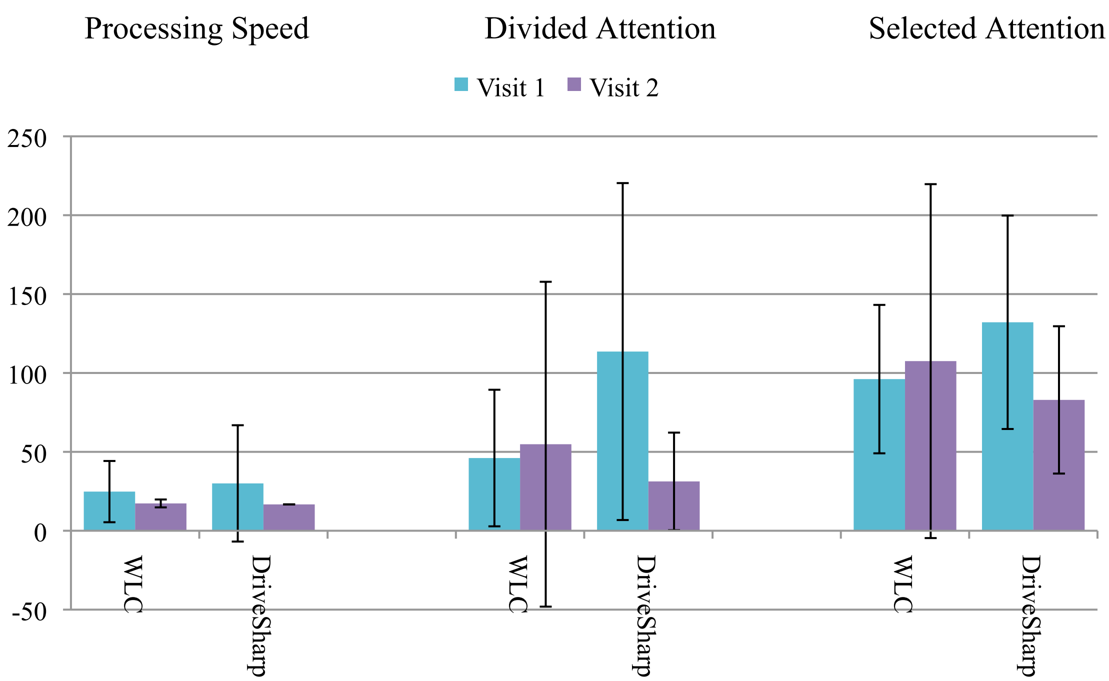
Figure 7. Waitlist control performance across 3 visits on the ANT.



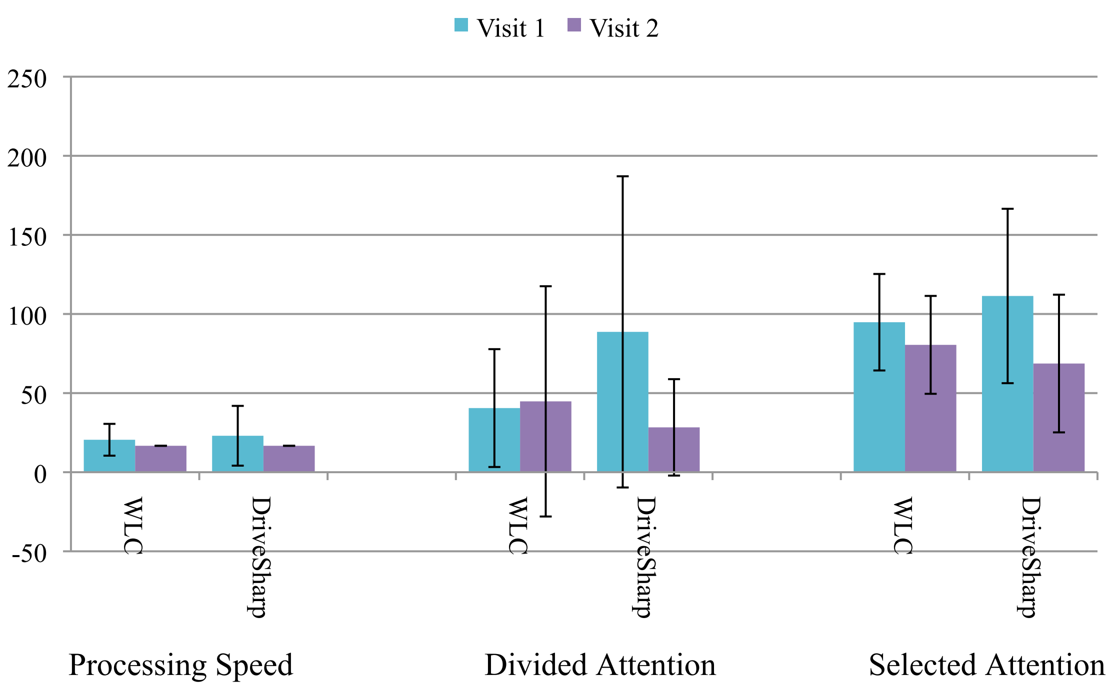
a = Visit 1 significantly different from Visit 2 ($p \leq 0.05$)
b = Visit 2 significantly different from Visit 3 ($p \leq 0.05$)
c = Visit 1 significantly different from Visit 3 ($p \leq 0.05$)

Figure 8. Performance on UFOV measures between groups within visits.

Total Sample

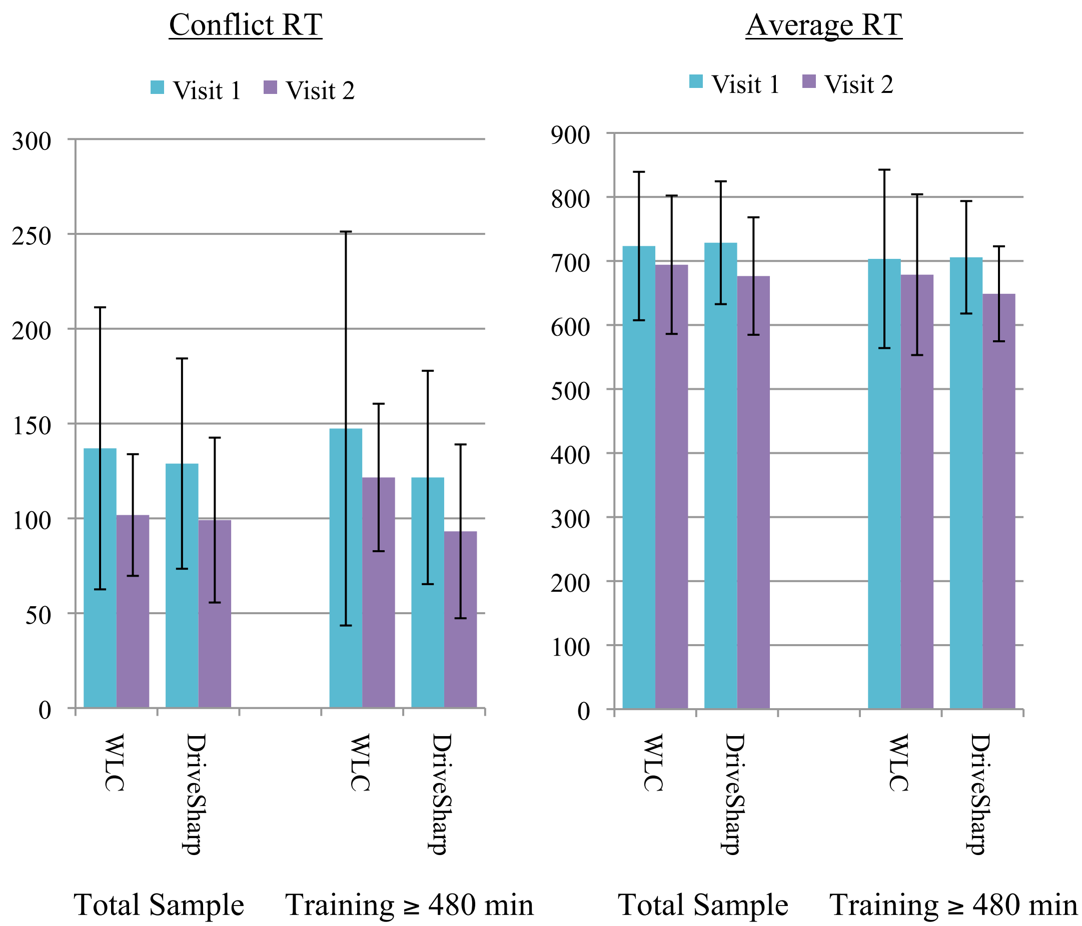


Training ≥ 480 min



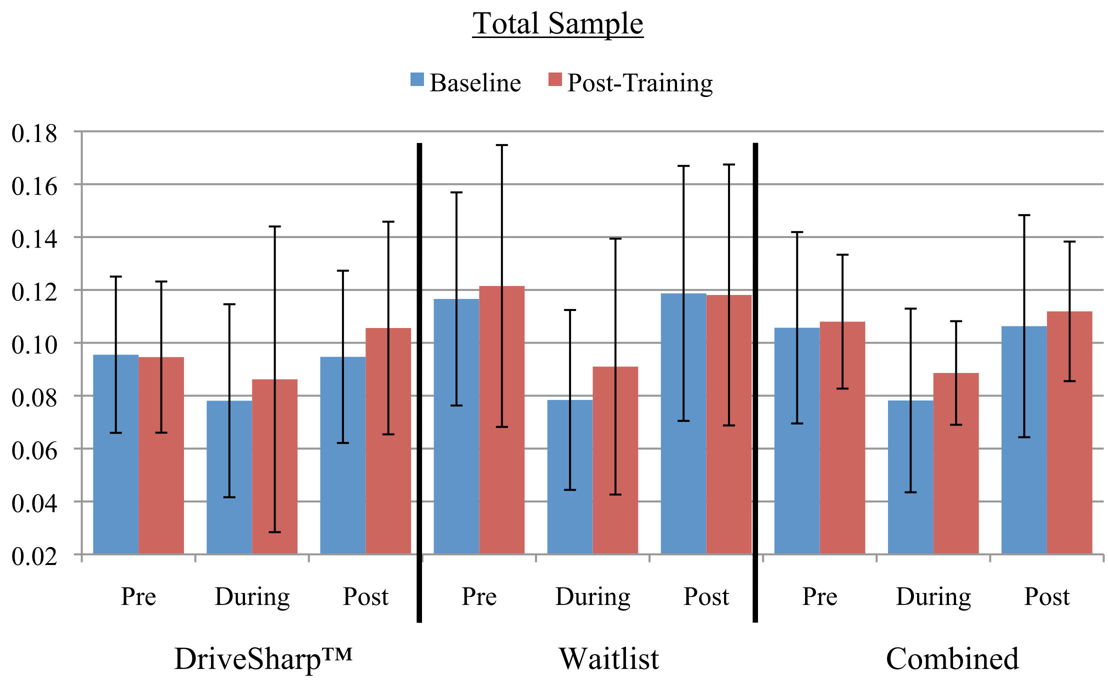
* denotes significance (p-value ≤ 0.05)

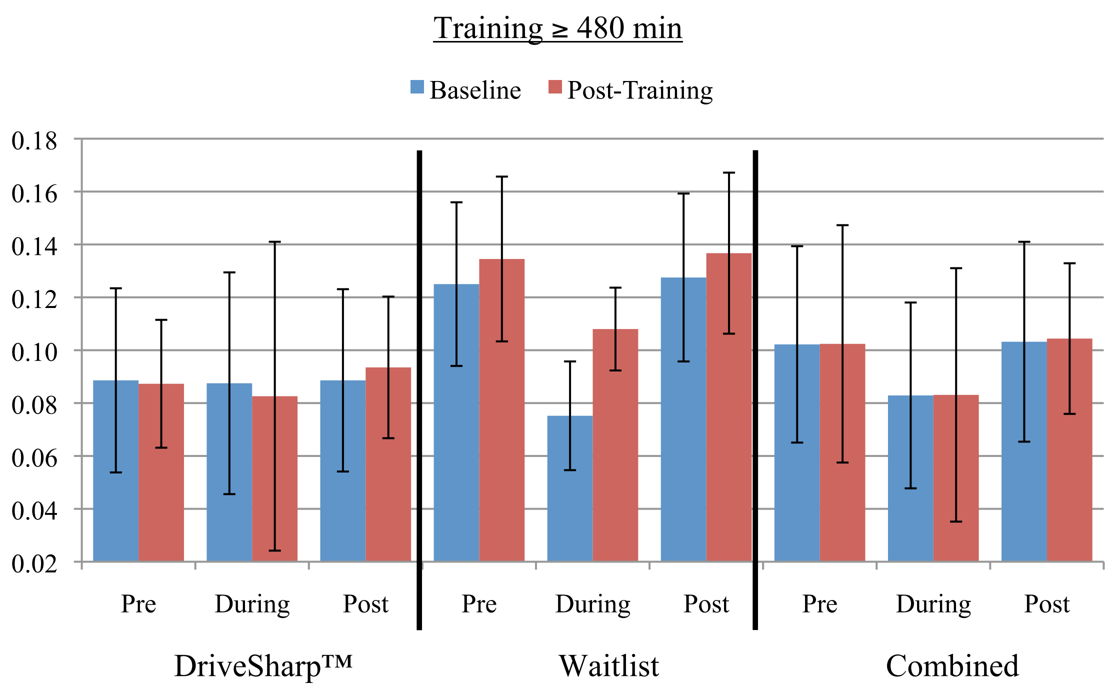
Figure 9. Performance on ANT measures between groups within visits.



* denotes significance (p-value ≤ 0.05)

Figure 10. Horizontal eye-gaze while driving and performing auditory working memory task between Baseline and intervention with DriveSharp™

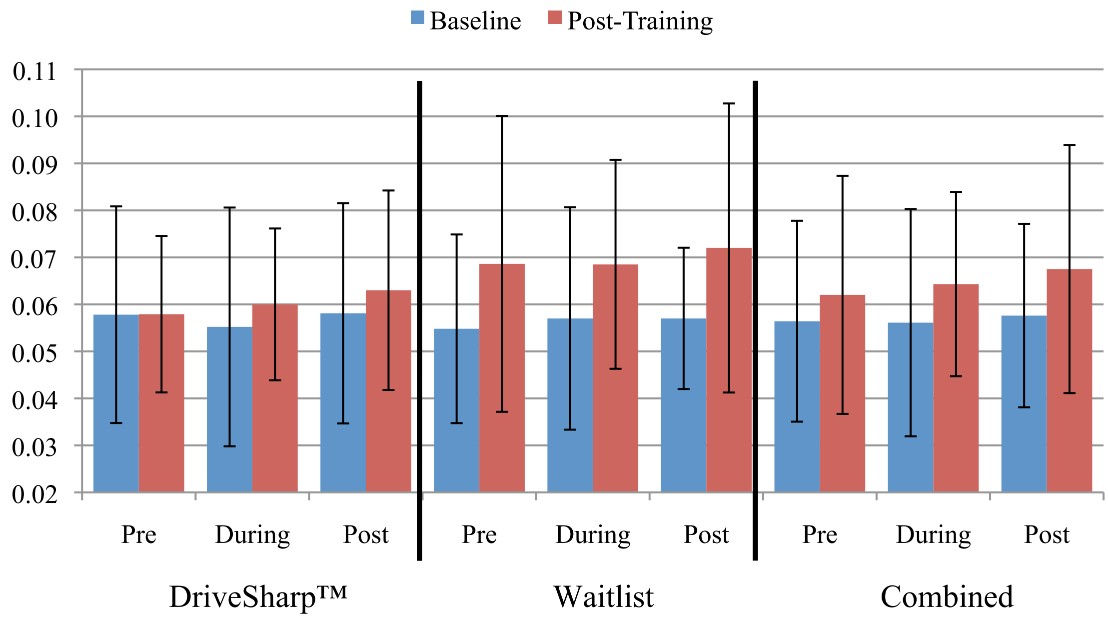




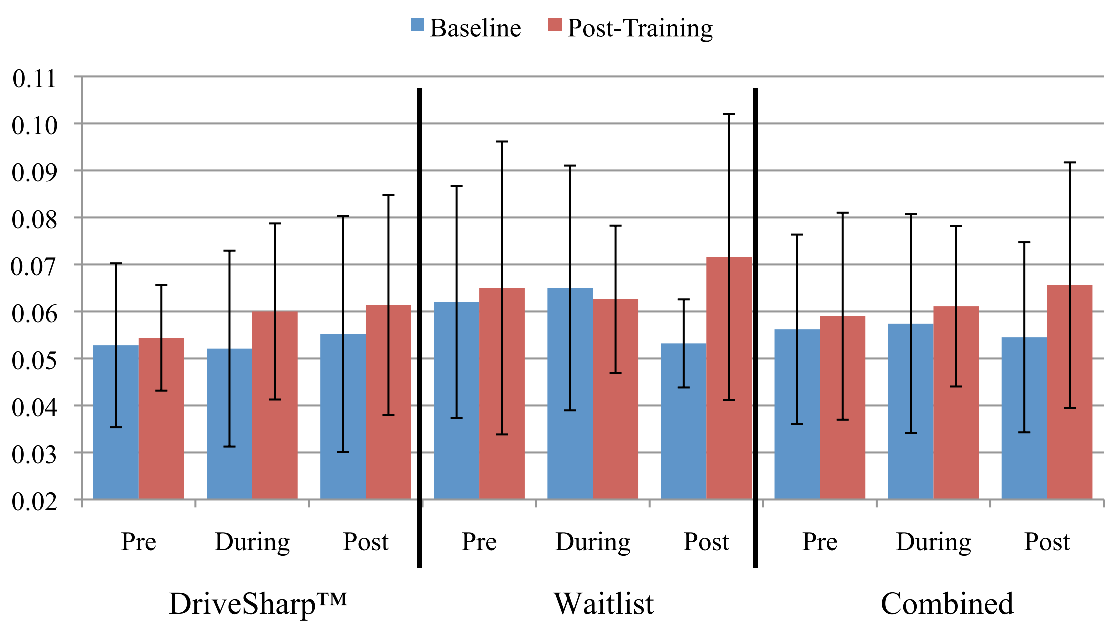
* denotes significance (p-value ≤ 0.05)

Figure 11. Vertical eye-gaze while driving and performing auditory working memory task between Baseline and intervention with DriveSharp™

<u>Total Sample</u>



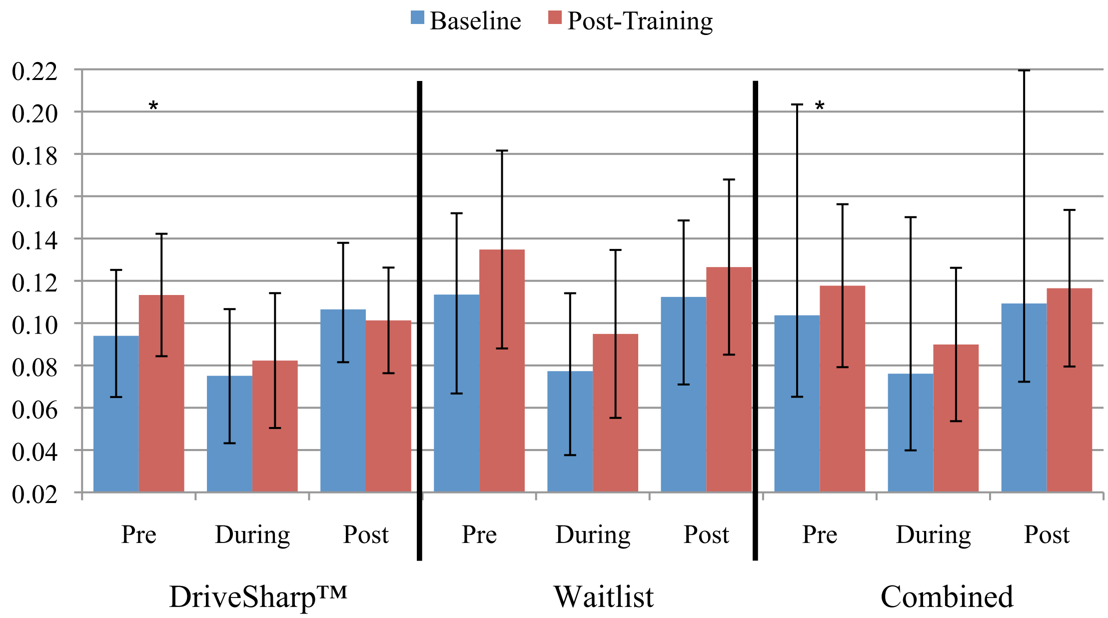
<u>Training ≥ 480 min</u>



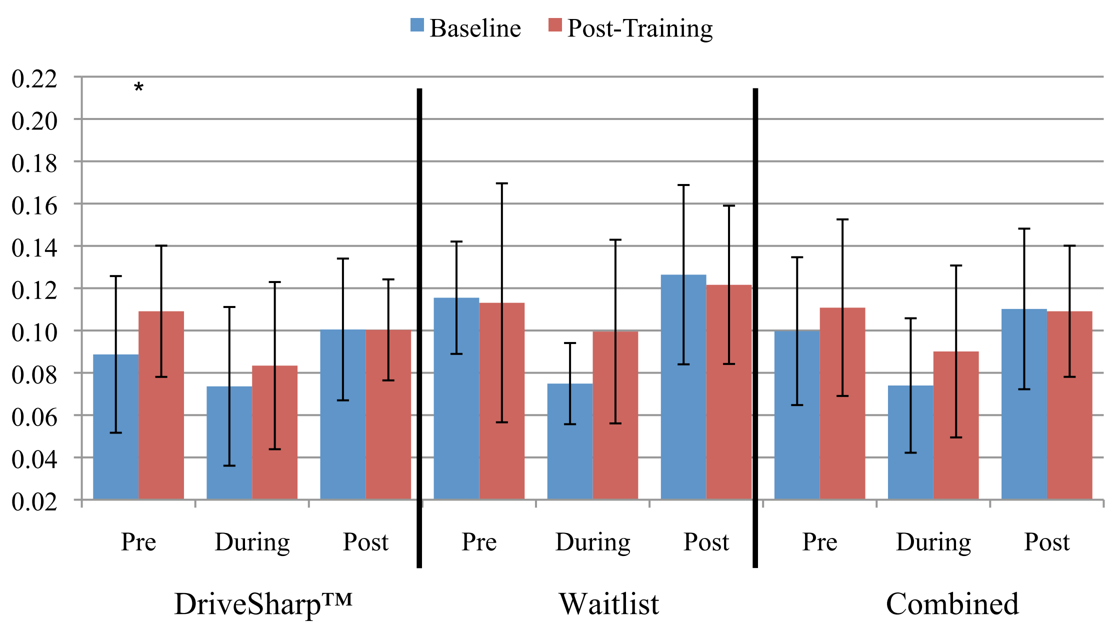
* denotes significance (p-value ≤ 0.05)

Figure 12. Horizontal eye-gaze while driving and performing visual working memory task between Baseline and intervention with DriveSharp™

Total Sample



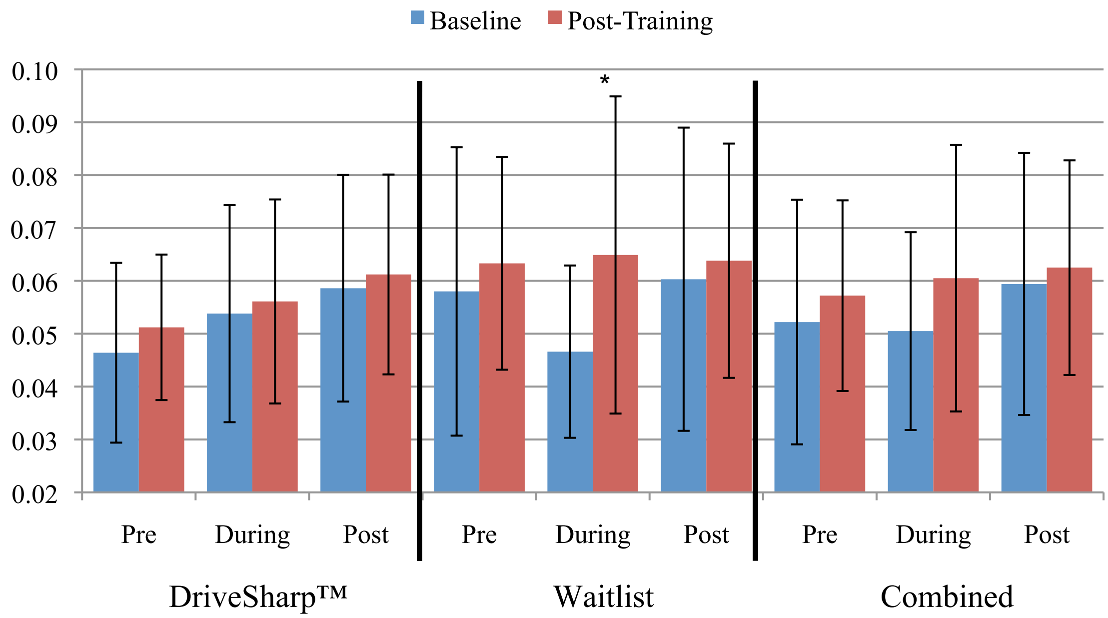
Training ≥ 480 min



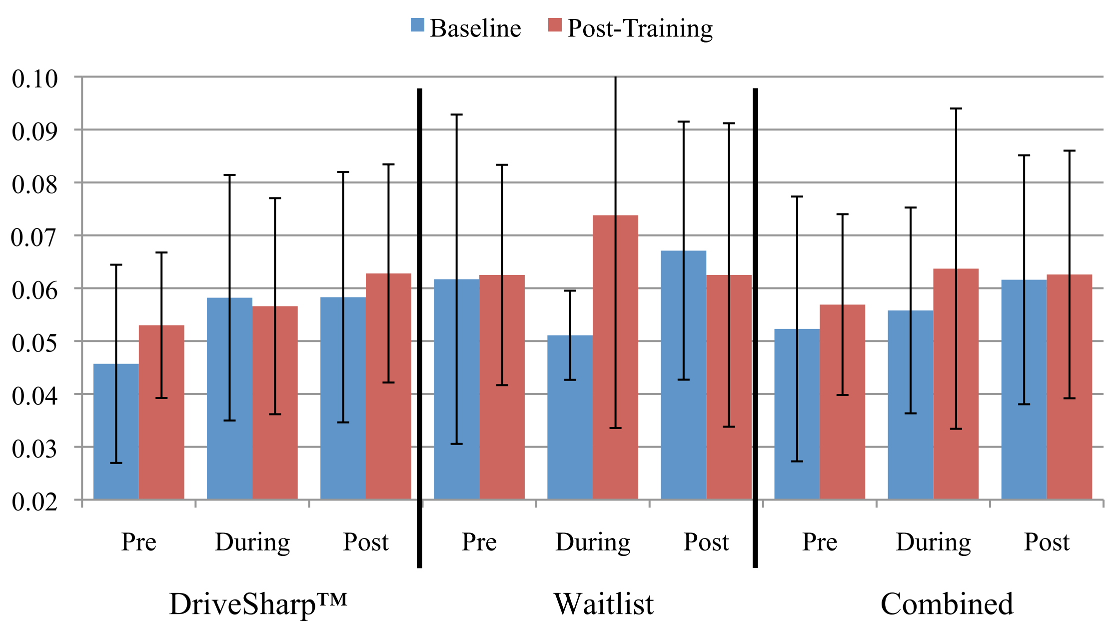
* denotes significance (p-value ≤ 0.05)

Figure 13. Vertical eye-gaze while driving and performing visual working memory task between Baseline and intervention with DriveSharp™

Total Sample

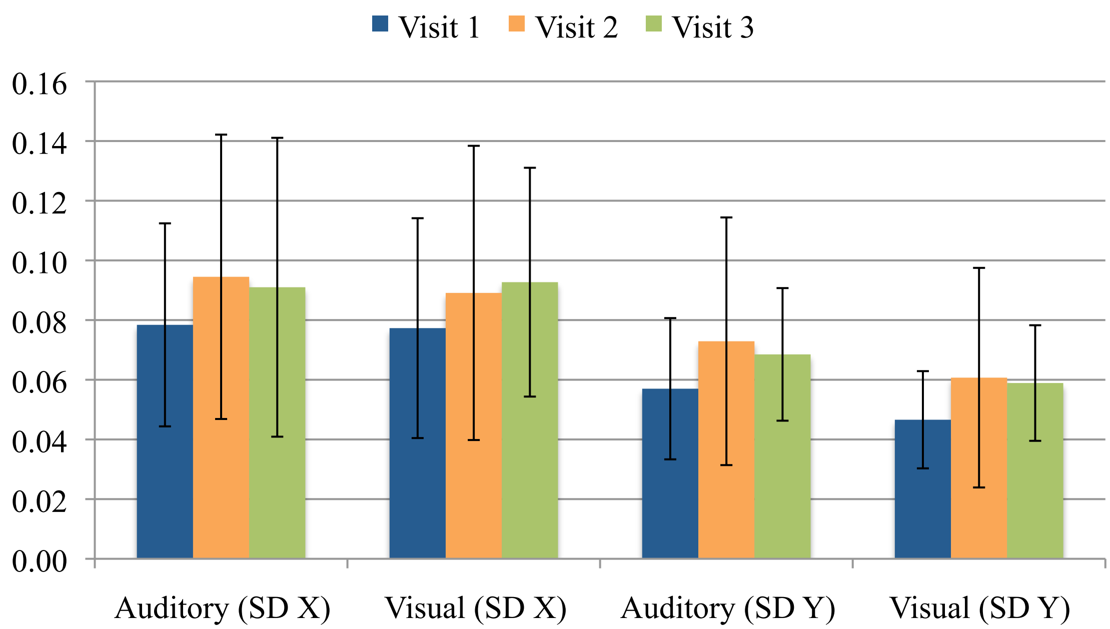


Training ≥ 480 min



* denotes p-value < 0.05

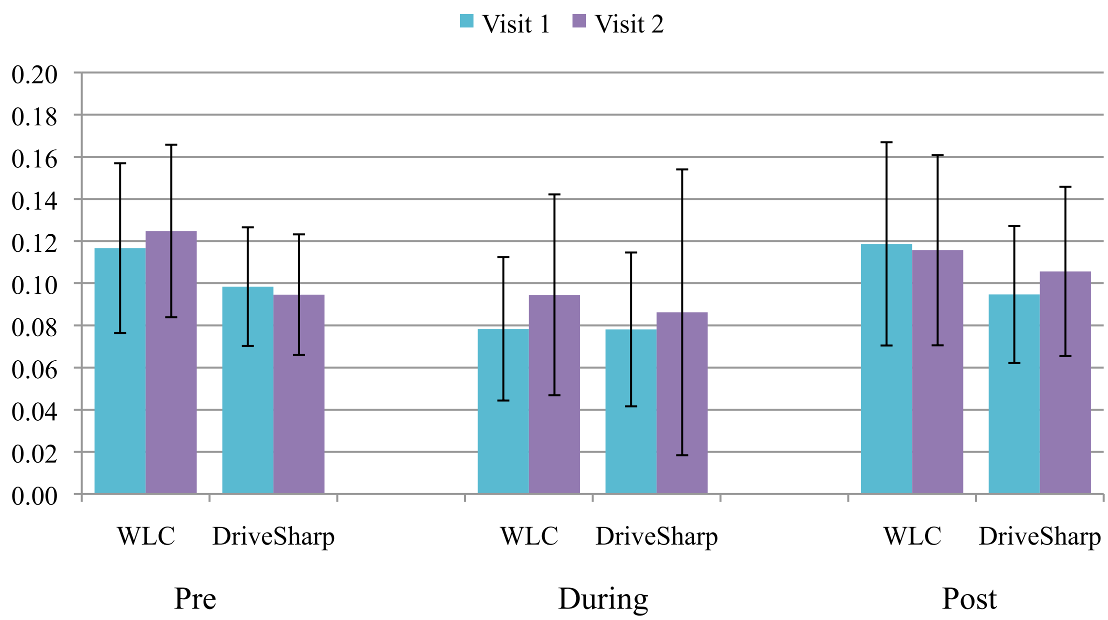
Figure 14. Waitlist control performance across 3 visits on eye gaze during the cognitive tasks.



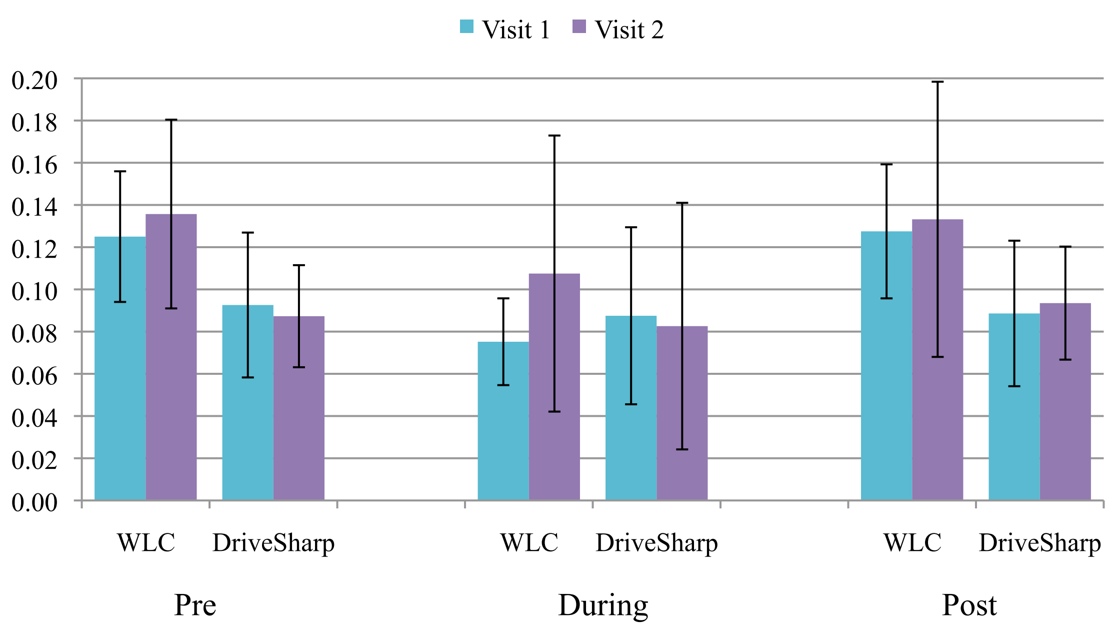
a = Visit 1 significantly different from Visit 2 ($p \leq 0.05$)
b = Visit 2 significantly different from Visit 3 ($p \leq 0.05$)
c = Visit 1 significantly different from Visit 3 ($p \leq 0.05$)

Figure 15. Horizontal eye-gaze while driving and performing auditory working memory task between groups (Visit 1 and Visit 2).

<u>Total Sample</u>

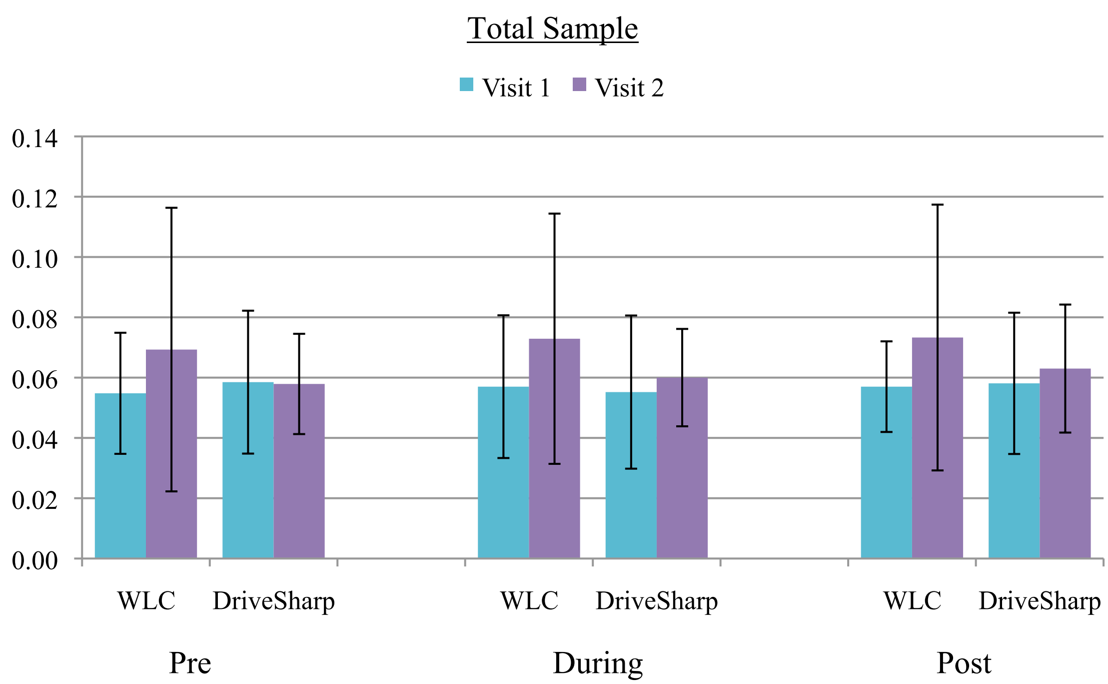


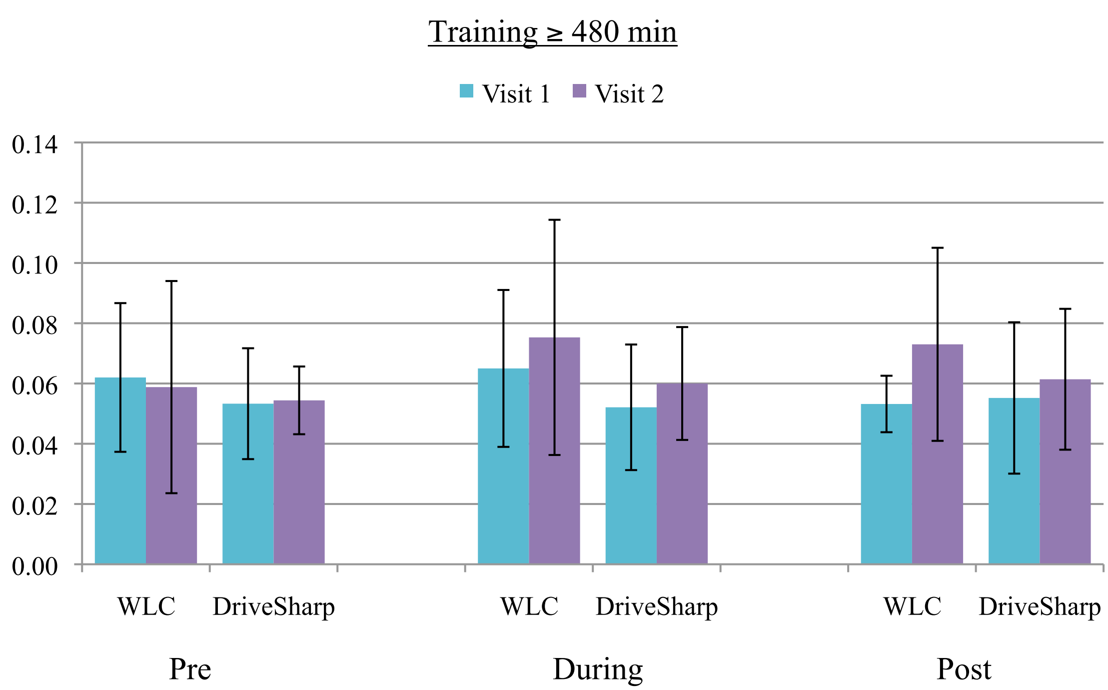
<u>Training ≥ 480 min</u>



* denotes p-value < 0.05

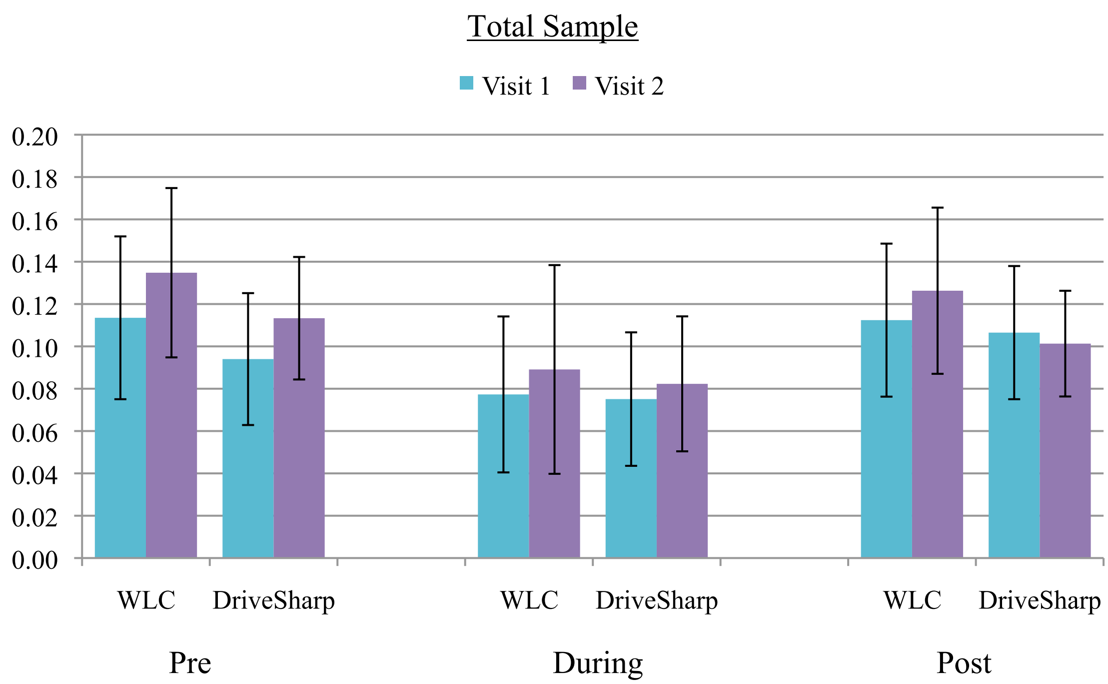
Figure 16. Vertical eye-gaze while driving and performing auditory working memory task between groups (Visit 1 and Visit 2).

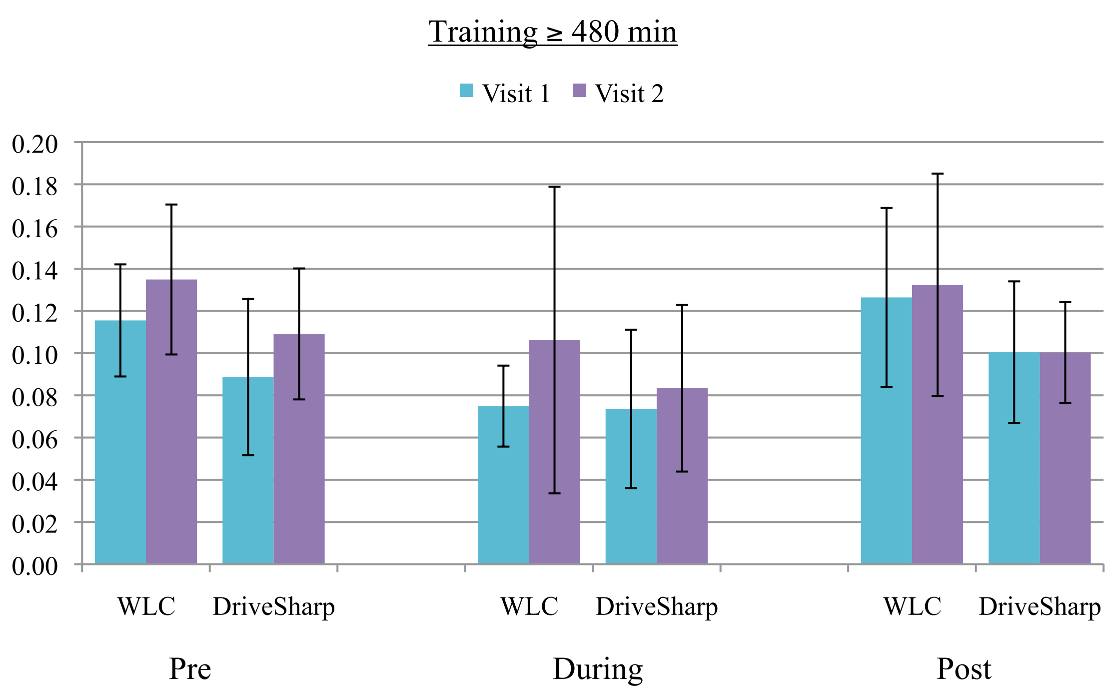




* denotes p-value < 0.05

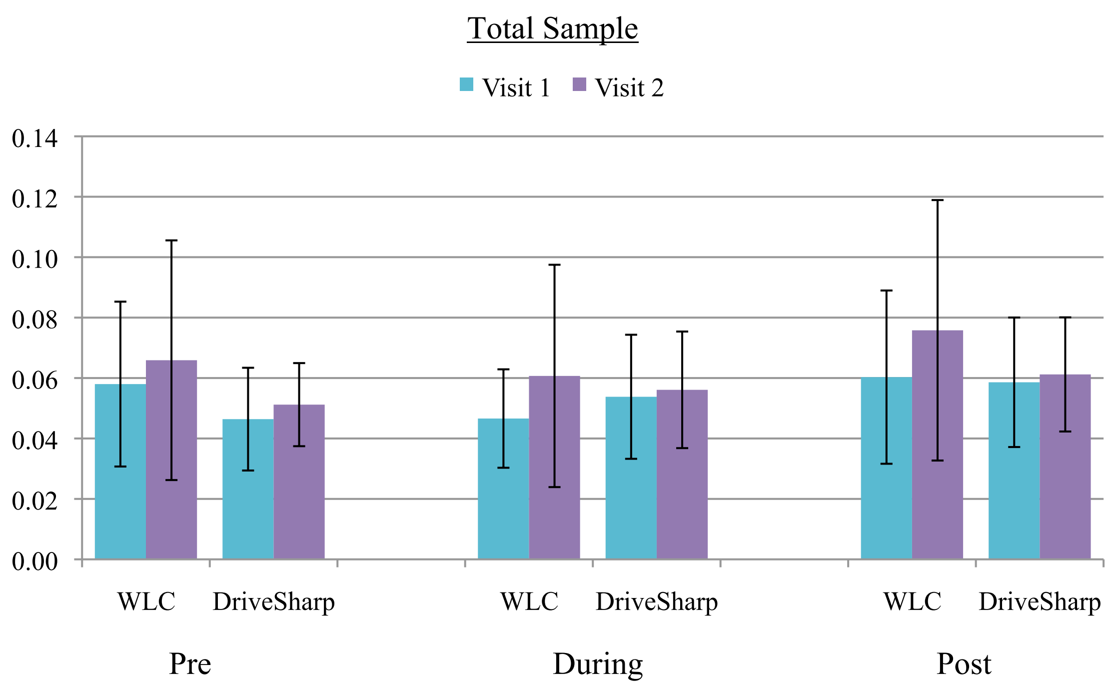
Figure 17. Horizontal eye-gaze while driving and performing visual working memory task between groups (Visit 1 and Visit 2).

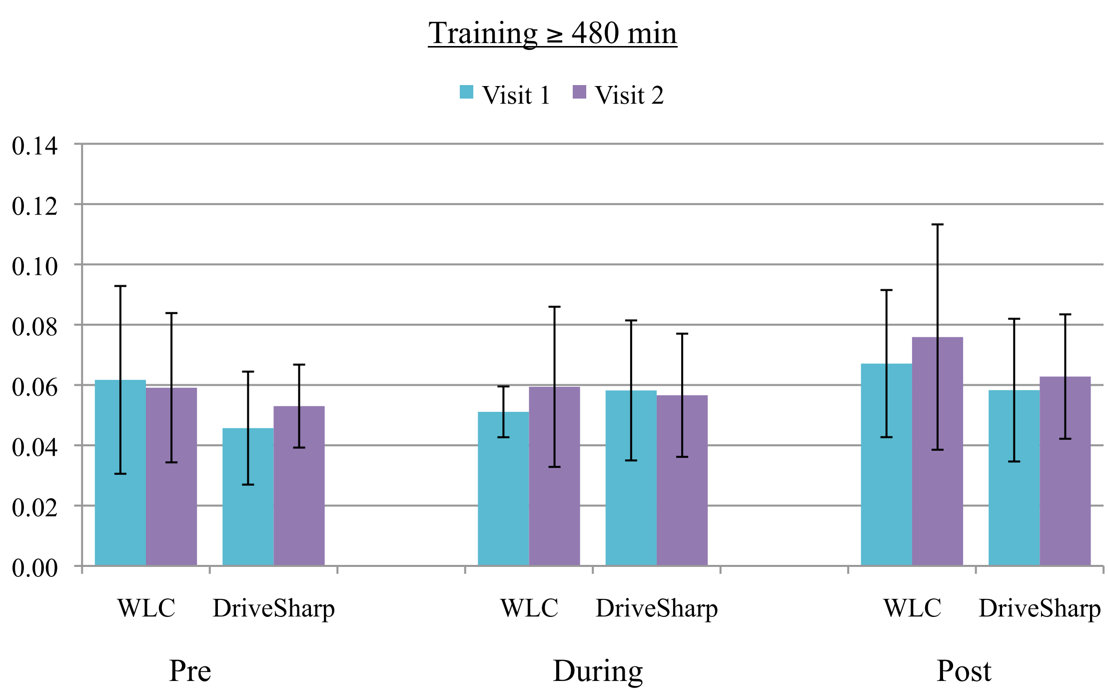




* denotes *p*-value < 0.05

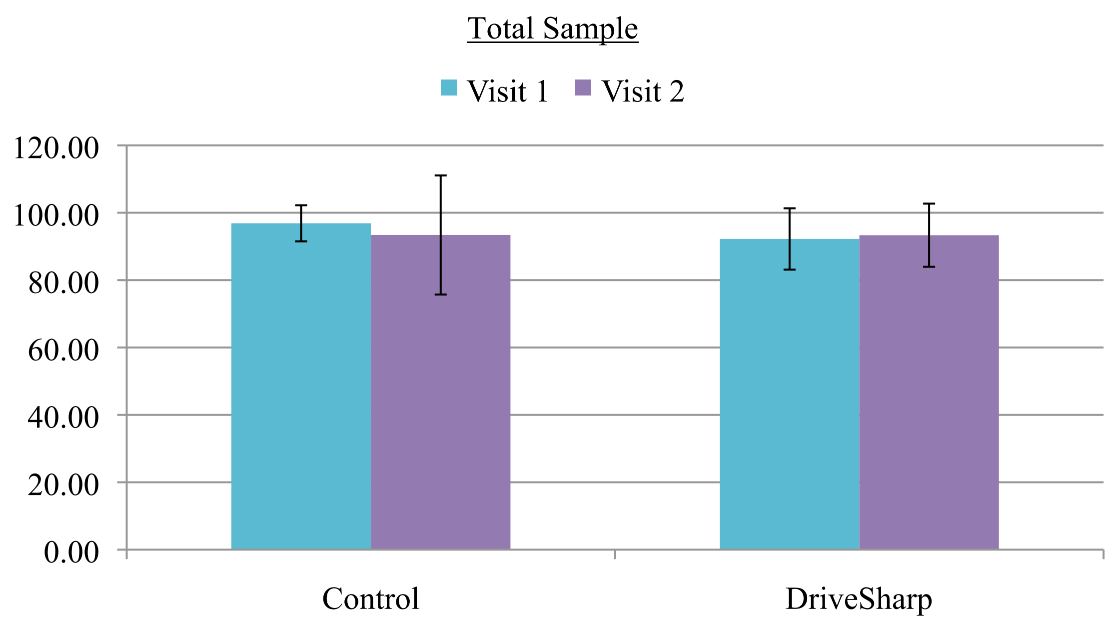
Figure 18. Vertical eye-gaze while driving and performing visual working memory task between groups (Visit 1 and Visit 2).

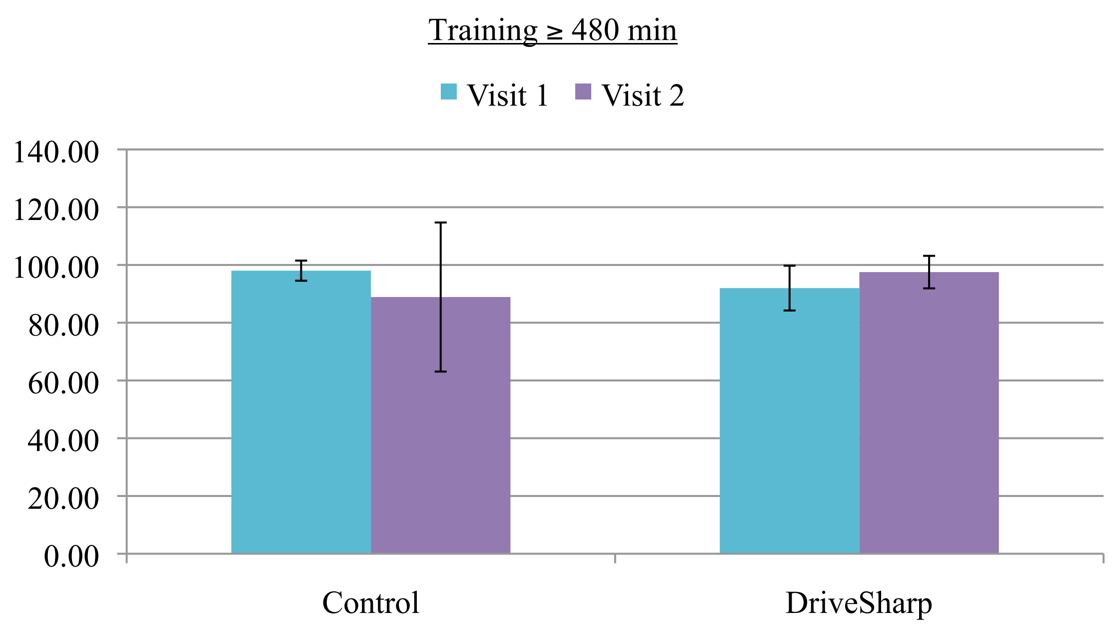




* denotes p-value < 0.05

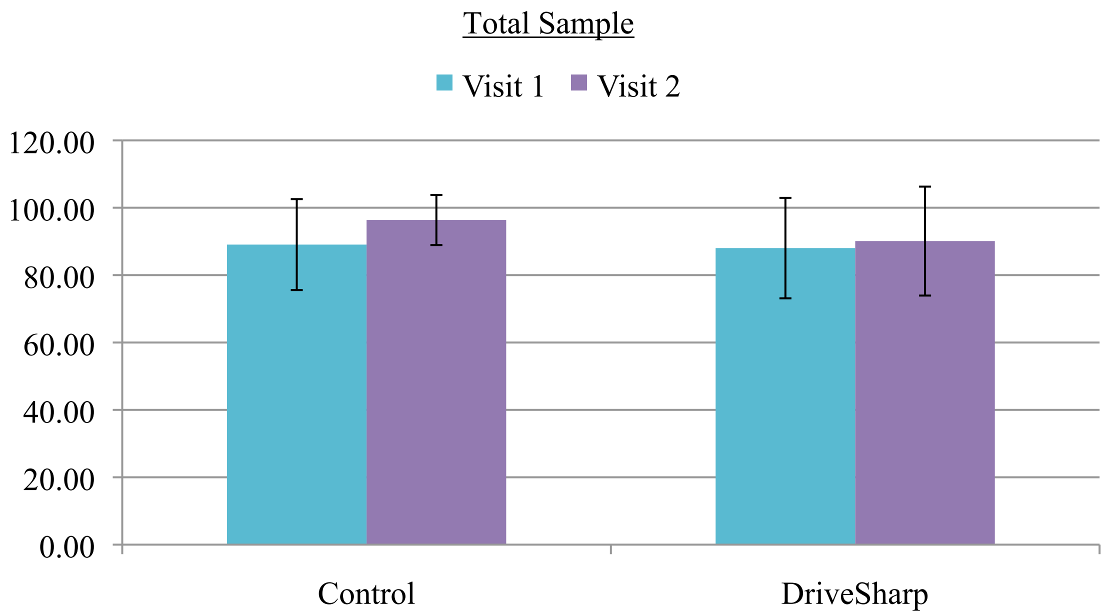
Figure 19. Performance on auditory working memory tasks during on-road driving between visits (Visit 1 and Visit 2).

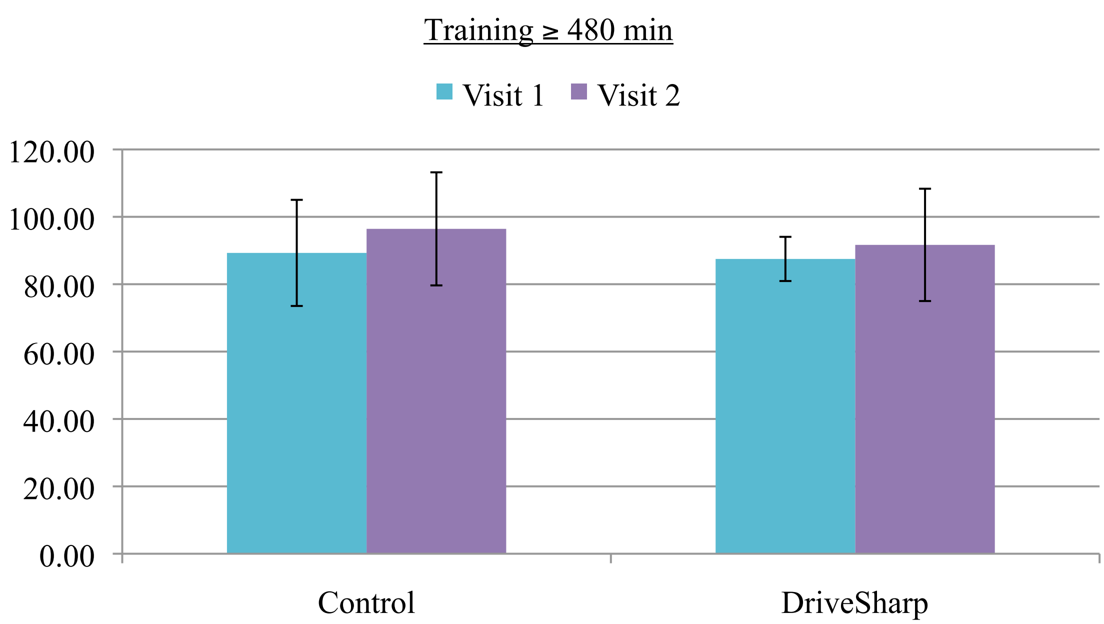




* denotes significance between groups (p-value < 0.05)

Figure 20. Performance on visual working memory tasks during on-road driving between visits (Visit 1 and Visit 2).





* denotes significance between groups (*p*-value < 0.05)

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