

EXAMINING VISUAL PROCESSING REACTION TIME AS A PREDICTOR FOR
DRIVING FITNESS

By

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December, 2023

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Rationale: As a complex IADL, driving is essential for social participation and quality of life. As such, it should be addressed by occupational therapy practitioners. Visual processing speed is a critical component of driving ability. Advanced age and medical conditions impact visual processing speed, therefore affecting driving risk. Although assessments of visual processing speed are limited, it can be isolated as a discrete ability when using a tool such as the Vision Coach™. **Purpose:** This research examined visual processing speed reaction times between medically-at-risk drivers and healthy controls with the purpose of determining its relationship with the outcomes of a comprehensive driving evaluation. Three research questions were specifically targeted: (1) is there a statistically significant difference of reaction times on the Vision Coach™ between the age groups of the healthy controls, (2) is there a statistically significant difference in visual processing speed reaction times across age groups between the healthy controls and medically-at-risk, (3) does the Vision Coach™ demonstrate adequate sensitivity and specificity to predict driving fitness outcomes? **Design:** Data collection consisted of a comprehensive driving evaluation including an on-road component for medically-at-risk adults with a fitness to drive outcome designated as “pass” or “fail.” The Vision Coach™ Full Field 60 task collected visual processing speed reaction times of the medically-at-risk adults as

well as healthy controls to compare between the two groups, between age groups, and determine predictability between driving fitness outcome. **Results:** One-factor ANOVA showed a significant ($p < .001$) difference in visual processing speed reaction times between all age groups of the healthy controls. Two-factor ANOVA showed a significant ($p < .001$) difference between age groups of the healthy controls and medically-at-risk as well as between the two groups as whole. Using the default cut point of 0.5, a logistic regression model determined the Vision Coach™ accurately predicted 86.4 percent of the driving fitness outcomes. The AUC was significant ($p = .001$) at .905 for outstanding diagnostic performance. **Conclusion:** Results of this study show that medical risk for driving impacts visual processing speed reaction times, regardless of age. The Vision Coach™ is a reliable and valid tool to assess and improve this discrete ability and can be used by generalists and specialists to help determine driving fitness.

EXAMINING VISUAL PROCESSING REACTION TIME AS A PREDICTOR FOR
DRIVING FITNESS

A Thesis

Presented to the Faculty of the Department of Occupational Therapy

East Carolina University

In Partial Fulfillment of the Requirements for the Degree

Master of Science in Occupational Therapy

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December, 2023

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Chapter I: Introduction

The largest increase in the population of older adults is projected to occur between the decades of 2020 and 2030, as the baby boomer generation begins to turn 65 years and older (Colby & Ortman, 2014). As of 2019, the population of older adults in the US was 54.1 million, representing 16 percent of the population, and projected to be 21.6 percent of the population by 2040 (Administration for Community Living, 2021). The 85 and older population is expected to more than double from 6.6 million in 2019 to 14.4 million by 2040 (Administration for Community Living, 2021). As of 2019, older adults accounted for 20 percent of all drivers in the US, and this age group typically demonstrates safe driving behaviors such as wearing seat belts more often, self-regulation by driving when conditions are safest, and not driving while under the influence of alcohol (Centers for Disease Control and Prevention [CDC], 2021). Although older adults engage in these safer driving behaviors more than other age groups, they were still involved in 15 percent of all fatal car accidents (National Highway Traffic Safety Administration [NHTSA], 2021).

The normal aging process can involve motor, visual, and cognitive decline (National Institute on Aging [NIA], 2018). This can include stiff joints and muscles causing decreased mobility when turning and steering, as well as braking safely. Eyesight may decline, making it more difficult to see and identify people, signs, and movements in peripheral vision (NIA, 2018). Decreased hearing can also lead to difficulty when driving due to not being able to hear horns or sirens from emergency vehicles. Slower reaction times and decreased reflexes can increase driving risk as well (NIA, 2018). These age-related declines in function can contribute to older drivers having increased driving risk and being involved in more car accidents, although they may not be diagnosed with specific medical impairments. In addition, there are some medical

diagnoses such as age-related macular degeneration, cataracts, and glaucoma, that can affect eyesight and therefore, driving (NIA, 2021). Diabetes is also a common diagnosis among adults that can lead to diabetic retinopathy which affects vision, or peripheral neuropathy that affects sensation in extremities (NIA, 2021). Medical diagnoses such as Parkinson's disease or stroke can also create physical limitations that negatively impact driving (NIA, 2018). Although healthy older adults experience normal age-related decline in function, medically-at-risk adults may experience a greater amount or faster declines in function.

Medically-at-risk adults can be defined as people who have a medical diagnosis that may impair driving ability, but are not related to typical aging (Pierce & Schold Davis, 2010). These adults may require a comprehensive driving evaluation to determine their fitness to drive. A comprehensive driving evaluation is an in-depth evaluation of performance skills and client factors that are related to driving, and it typically composed of an on-road evaluation and a clinical evaluation (Pierce & Schold Davis, 2010). Fitness to drive can be defined as the absence of any function deficit or medical condition that significantly impairs an individual's ability to control a vehicle or significantly increases crash risk (Transportation Research Board [TRB], 2016). The typical aging process causes older adults to experience disruptions in skills necessary for driving, as does many medical diagnoses. It is imperative to be able to screen and assess both of these populations for fitness to drive, as needed.

Driving is considered to be one of the most meaningful Instrumental Activities of Daily Living (IADL) for older adults (Dickerson et al., 2013). Driving is also the most common form of transportation used by older adults to engage in social activities and complete daily routines (Luiu et al., 2017). The growth of suburban areas has led to many people becoming more dependent on driving for daily living; rural and suburban communities essentially require motor

vehicles as the main form of transportation, and therefore the main means of facilitating participation (Filion, 2018). As driving is considered an enabling occupation, in relation to its role in community mobility and social participation, driving cessation can be a barrier to participation (Dickerson et al., 2013).

Community mobility occurs across the lifespan, and it comes in many forms of transportation such as public transportation, driving, or even riding a bike (Schold-Davis, 2012). There is a high correlation between satisfaction with access to the community and quality of life in older adults in relation to being able to engage in meaningful activities (Mulry et al., 2019). Driving supports participation, and transportation has been linked to feelings of independence, autonomy, and quality of life across all ages (Carp, 1988). One study shows that driving cessation causes a decrease in social participation as well as an increase in dependence, causing strains on familial relationships and having a negative impact on overall personal well-being and quality of life (Taylor & Tripodes, 2001). It has been determined that the ability to engage in social, civic, and community life that fosters interaction is heavily reliant upon safe mobility (Dickerson et al, 2007). As stated above, quality of life is closely tied to the ability of one to feel independent, and driving is an enabling activity that provides means for independence.

Driving cessation has also been linked to increased prevalence of depression, which is a decrease in psychological well-being and quality of life (Fonda et al., 2001; Marottoli et al., 1997). Ratnapradipa et al., (2019) also found survival rates among those who resumed driving after driving cessation were much higher than those who did not, further demonstrating the adverse health and social outcomes associated with driving cessation. Determining driving risk and influencing driving cessation may impact mental health and quality of life for many individuals, and should therefore be assessed carefully and thoughtfully.

Occupational therapists assist clients with participation in necessary and desired occupations (AOTA, 2020). Occupations fall into the categories of education, work, play, leisure, social participation, rest and sleep, health management, activities of daily living (ADLs) (ex. dressing, bathing, and eating), and instrumental activities of daily living (IADLs) (ex. finance management, meal preparation, and driving) (AOTA, 2020). To provide care in these areas, occupational therapists are trained to skillfully evaluate all aspects of the occupational therapy domain related to a client: occupations, contexts (ex. environmental and personal factors), performance patterns (ex. habits, routines, roles, and rituals), performance skills (ex. motor, process, and social interaction skills), and client factors (ex. values, beliefs, spirituality, body functions and body structures) (American Occupational Therapy Association [AOTA], 2020). Occupational therapists are skilled to evaluate how these domains interact and impact participation in occupations.

The aim of occupational therapy is to achieve health, well-being, and participation through the use of occupation (AOTA, 2020). Looking at every aspect of a person's life, occupational therapists are especially qualified to address driving: evaluating or intervening based on individual performance, or for public safety (AOTA, 2016). Community mobility and driving is also delineated as an IADL as part of occupational therapy's scope of practice (AOTA, 2014). Occupation-based assessments and tools should be determining driving risk through functional performance and processing speed, but the current tools being used by professionals focus on measuring individual driving skills such as motor coordination or visual acuity (Dickerson, 2013). This study will analyze the ability of the Vision CoachTM, a tool created by occupational therapists for measuring cognitive processing speed, to predict fitness to drive.

Chapter II: Literature Review

Driving Risk in Older Adults

Over the past 10 years the data consistently shows adults 65 years and older as having higher motor vehicle fatality rates than those younger than 65 (NHTSA, 2021). Multiple risk factors have been identified as potential causes for increased driving risk among older adults due to age-related decline, mostly due to having a physical, sensory, or cognitive impairment (Dellinger, 2012). Degradation of visual and motor skills, as well as cognitive processes, can have a negative impact on driving abilities in older adults (Payyanadan et al., 2018). Cognitive impairment rates among older adults are reportedly 1 in 7 over the age of 71 (Plassman et al., 2007). As cognitive impairment can impact judgment, decision-making, and processing speed, among other client factors, it is shown to impact driving risk among older adults (Adler & Kuskowski, 2003). These deficits may be age-related or impairment-induced, so age is not the only factor that can contribute to driving risk.

Although age should not be the only indicator for driving risk, studies show that fitness to drive is reduced as age increases; those 85 years and older are generally more likely to be considered unfit to drive based on increased numbers of motor vehicle crashes and unsafe driving as determined by physicians and driving evaluation specialists (Moon et al., 2018). Driving is a complex IADL, requiring multiple functional abilities such good vision under high- and low-contrast conditions, cognitive processing speed, and mobility (Staplin et al., 2003). This means that fitness to drive determinations must cover an array of functions from motor to cognition. Not just one test can determine fitness to drive, as the array of determinants span further than the capability of just one test (Dickerson, 2014). Finding the correct batteries of assessment tools that, when combined, most closely predicts fitness to drive in both specificity

and sensitivity is key to determining driving risk (Wood et al., 2013). Many adults experience decreased cognitive and motor ability due to the natural aging process, and medically-at-risk adults are often confronted with decisions regarding driving cessation for safety purposes. The risks associated with driving can be delineated by Michon's (1985) hierarchy of driving behaviors.

The hierarchy begins with the operational level, which is the lowest, most basic and overlearned aspects of driving. These are the automatic skills that do not typically require forethought for completion such as turning the steering wheel, applying the brakes, and using a turn signal. Although these may be aspects of motor memory, but ultimately relate to the individual's ability to control the vehicle. The second level is the tactical level, and this includes skills that are utilized immediately to make quick decisions while driving. Typically, these skills are determined by the rules of the road, road signs, generally following traffic laws and being able to maneuver while driving. The third level is the strategic or planning level. This involves planning for a trip, determining the best route, performing a cost/benefit analysis for each of these decisions; it can also account for navigational decision that must be made if there is construction or the route needs to be altered in some way due to an accident (Michon, 1985; TRB, 2016). This requires the higher level cognitive functioning that may be in decline for adults as they age, as well as medically-at-risk adults. This model includes motor, visual, and cognitive processing skills as integral to driving.

Motor Function in Driving Skills

Three main domains of function typically denote the requirements for safe driving skills: visual, cognitive, and motor skills or function (Desapriya et al., 2014). Multiple functions fall under these domains such as reaction time, processing speed, range of motion, and visual and

motor skills, just to name a few. Physical frailty and contrast sensitivity were found to have negative impacts on driving performance, indicating that deficits in muscle strength, coordination, gait and/or balance and vision could be determinants in driving risk (Carr et al., 2016). Studies have also shown that some of the physical traits that indicate a fall risk are also associated with at-risk driving, for example reduced peripheral sensation, lower extremity weakness, slow reaction time, and poor balance during observation (Lacherez et al., 2014). Flexibility in the head, neck, and upper torso are needed for driving, as well as lower extremity strength and mobility for operating the pedals in the vehicle (Lacherez et al., 2014). Motor skills and functions are clearly delineated in the research as an indicator of driving risk, but there is a need for a battery of physical tests in order to determine physical fitness to drive (Mielenz et al., 2017). Alternatively, some studies have found that motor function is not typically predictive of driving outcomes, and only weak evidence to support assessing physical abilities and skills as indicators of fitness to drive (Carr et al., 2011). Dickerson et al., (2011) found that the motor skills was not significant in differentiating between those who passed the driving test and those who failed, which suggests that motor abilities are not always indicative of whether someone will pass a behind-the-wheel (BTW) assessment.

Most healthy older adults will experience a decline in physical ability and visual acuity, but many of these deficits can be fitted with compensatory techniques that enable continued participation in IADLs such as driving (Moon et al., 2018). Occupational therapists, as listed within their scope of practice, adapt and modify activities and environments in order to facilitate occupational participation (AOTA, 2020). Some physical limitations can come about due to age-related decline or genetic disorders such as Parkinson's disease, and some of these functional limitations while driving can be addressed by occupational therapists. Adaptive equipment can

be utilized, compensatory techniques can be integrated, and the physical and motor skills can be altered to enable continued participation in driving. For example, altering the vehicle to accommodate hand controls for those with weakened lower extremities or paralysis (Hegberg, 2012). Since some physical limitations can be overcome, driving risk assessments would determine whether certain limitations should result in driving cessation or if adaptations and compensatory techniques would be sufficient to remedy those functional deficits. Even some deficits in vision can be remedied with eyeglasses or surgeries, making some visual deficits adaptable to continue driving.

Visual Function in Driving Skills

Older adults can experience low vision, which is typically defined as “a degree of visual impairment that cannot be corrected by eyeglasses or surgery and that interferes with daily functioning” (Rudman & Durdle, 2009, p. 106). Low vision can have multiple causes such as diabetic retinopathy, glaucoma, stroke, cataracts, and age-related macular degeneration, but typically present with similar functional deficits (Justiss, 2013). These deficits can include decreased contrast sensitivity as well as decreased dynamic and static visual acuity and visual field loss (Justiss, 2013). A study reports that older adults with low vision have a higher risk of being involved in a vehicle crash than all other age groups (Stalver & Owsley, 2003). Low vision deficits such as visual field loss and diminished acuity can be addressed using compensatory options such as adaptive mirrors and other specialized low vision devices, but some deficits may be too advanced, requiring driving cessation (Justiss, 2013).

Proper visual testing is imperative to determining driving risk as low vision deficits impact older adults. Motion sensitivity has been tested to be the strongest visual predictor of driving performance, but on a closed-road circuit and has face validity in the context of driving

(Wood et al., 2008). The Useful Field of View (UFOV™) (Matas et al., 2014) has been shown to be a significant predictor of crash involvement, proving the importance not only of visual acuity, but functional vision as well (Rubin et al., 2007). On the other hand, visual acuity has been tested and found that alone it is not a strong enough predictor of driving risk (Green et al., 2013). The UFOV™ requires higher-order visual processing skills, including processing speed, and visual processing speed is considered more closely associated with driving risk than only visual acuity, making the case that a higher-order visual processing test is needed to determine driving risk (Hunt et al., 1993). The UFOV™ tests in Owsley's et al. (1998) study showed that there were no relationships between future crashes and deficits in visual acuity, contrast sensitivity, or visual field sensitivity. The strongest evidence for UFOV™ has been reported in its Subtest 2, which measures processing speed (Classen et al., 2013).

Studies show that although older drivers with visual impairments are at a higher risk for being involved in a vehicle-related crash or accident, interventions based in education of vision and its impacts on driving may be beneficial for decreasing that driving risk (Classen et al., 2014). Addressing self-perceptions of driving skills would also increase self-regulatory behaviors, with studies showing this reduced driving exposure but also increased avoiding driving situations that are more visually challenging for that individual (Classen et al., 2014). The consistent message the literature conveys is that there cannot be only one test to determine driving risk, and cognition and processing speed may be the most consistent predictors (Dickerson, 2014).

Cognitive Functions in Driving Skills

Changes in Cognition

Cognitive processes such as working memory and cognitive speed are impacted by age-related decline. Vonk et al., (2020) found that cognition declines linearly with age, and higher education did not impact that decline. Although cognitive decline can be caused by normal aging, it can also be caused by disorders such as Mild Cognitive Impairment (MCI) and dementia. MCI is a cognitive condition that involves memory or thinking deficits typically in older adults, presenting with symptoms like frequently losing things, forgetfulness, or being unable to remember certain words in conversation (NIA, 2021). Dementia can impact a person's judgment and reasoning skills, and often times people with dementia do not recognize or acknowledge these deficits; therefore, they may not make appropriate decisions related to driving (Adler & Kuskowski, 2003). Many older adults, although resistant to cease driving regardless of declines in health, do tend to self-regulate driving to decrease crash risk during questionable weather or in unfamiliar environments (Dellinger et al., 2001). This may come in the form of not driving at night, staying off busy highways or avoiding rush hour traffic, and staying within a familiar area, but these tendencies typically follow individual assessment of capabilities (Dellinger et al., 2001).

Since restrictions are placed on an individual basis, the determination of driving fitness is more dependent on individual performance rather than just the diagnosis the person may have. This is important to note for older adults that have dementia who may not be acknowledging cognitive deficits, and will ultimately be less likely to assess their capabilities objectively and make self-regulated modifications to their driving patterns. Physical modifications to the vehicle or retraining techniques cannot correct the deficits caused by dementia, unlike with a physical disability (Dickerson et al., 2007). There are no current strong evidence-based interventions or studies to support compensatory strategies to improve driving outcomes or capabilities for those

with dementia (Classen et al., 2014). Dementia is not the only disorder that can impact cognitive function. Su et al., (2015) found that while looking at six cognitive domains (processing speed, verbal memory, visual memory, visuoperceptual function, language, and cognitive flexibility) among healthy matched controls and stroke patients, that the only significant group difference was among processing speed. This suggests that decreased processing speed underlies cognitive disfunction in stroke patients. Understanding that medical diagnoses can impact cognitive functions that are necessary to driving is why the medically-at-risk population must be assessed for fitness to drive.

Understanding a specific medical diagnosis offers information that affects driving risk. This could mean that there are more specific assessments that are more appropriate for measuring fitness to drive in this population based on the impairment. Specific conditions have functional deficits that can be measured by assessment tools that can provide better predictive validity (Dickerson et al., 2014). Evidence was also found for the *Stroke Drivers Screening Assessment* (Nouri et al., 1993) being moderately predictive for driving outcome in people with stroke, but not other clinical conditions (Lincoln et al., 2006). It is important to note that at any age the medically-at-risk population can also be at risk drivers due to impairments caused by their conditions, and not just the natural aging process.

Executive Function

Visual and motor ability is necessary for driving, but executive functioning is imperative for perceiving and coordinating all of that input and turning it into appropriate output through functions such as: impulse control, planning, scanning, and attention (Classen et al., 2012). A meta-analysis found that although studies used different assessment tools as well as different outcome measures, it was consistently found that poor performance on the cognitive tests was

found in all drivers who failed the outcome measure (Mathias & Lucas, 2009). Impairment of executive functioning can be inadequate scanning or tracking and slowness of response, especially in more complex driving situations, and at a tactical level there may be a breakdown when a rapid sequence of responses is required (Van Zomeren et al., 1987).

Processing Speed in Driving Skills

Cognitive processing speed has strongly and consistently been associated with the ability to perform everyday tasks, and has had significant correlations with IADL performance, mobility, and driving in people with MCI (Wadley et al., 2021). As processing speed declines, it takes older adults longer to make decisions, especially while driving. This is problematic because driving can require fast decision-making in regards to navigation or traffic, and if slowed, it can lead to increased driving risk.

Cognitive processing capability can vary widely in older adults, and this can depend on age as well as any person's specific impairments. Processing speed is impacted by normal aging; increased age is associated with decreased processing speed (Salthouse, 1996). Studies show that reaction time also decreased with age, but variance increased; this demonstrates that there is considerable variability in age-related decreased processing speed that needs to be considered (Svetina, 2016). Tam et al., (2015) found that processing speed predicted general cognitive status among older adults, which is a composite of cognitive abilities that reflect full function.

Age is not the only indicator of decreased processing speed. Declines in cognitive function and processing speeds have been determined as the most significant indicators of variance in older adults and their ability to practice safe driving (Anstey et al., 2012). Visual-cognitive abilities, processing speed and speeded executive tasks are the strongest correlates of integral driving skills in older adults, as analysis placed executive measures and processing speed

in a single factor, making it impossible to separate the two by means of variance (Anstey et al., 2012). Hotta et al., (2018) found that although normal aging is correlated with increased driving risk, processing speed was more closely correlated with increased driving risk regardless of age. People can typically continue to drive with normal motor age-related changes as long as there are no major impairments, but this is not always the case with cognitive or processing speed deficits.

Interestingly, some studies suggest that speed-of-processing training (SPT) may improve driving. For example, Roenker et al., (2003) found it improved processing deficits that produced less driving risk, and that lasted for at least 18 months, supporting research that safe driving behaviors is highly correlated with cognitive processing speed. SPT in older adults also showed increased mobility and longevity in driving, and increased doses of the SPT for those with poor initial processing speeds showed even greater levels of self-reported driving maintenance and frequency (Ross et al., 2016). Although this study relied on self-reporting, it supports the research indicating that processing speed is indicative of driving performance in older adults and further research is needed to demonstrate to what degree speed of processing can be influenced and how that will impact driving risk outcomes. Visual reaction times and sustained attention are typically measured to help determine cognitive processing speed deficits (Barbarotto et al., 1998).

Assessment Tools to Assess Driving Risk

Current tools used by driving rehabilitation specialists when assessing driving risk typically focus on testing the individual skills of driving such as visual acuity, muscle strength, and motor coordination (Dickerson, 2013). Seong-Youl et al. (2014) found that the Trail Making Test B was the most effective, followed by Trail Making Test A and UFOV™, for assessing driving risk.

Trail Making Tests

The Trail Making Test B, which tests visual processing speed as well as divided attention, was found to be a better predictor of crash involvement than the UFOV™ (Friedman et al., 2013). Trail Making Test B results have indicated that slowed processing speed was able to identify older drivers who were at risk (Dickerson, 2013). This further supports the research that normal age-related decline can increase driving risk, but a better predictor for driving risk is cognitive processing speed because it is still a predictive measure even when age is controlled for. The importance of cognition and processing speed in determining driving risk is clear, as well as the lack of proper functional and performance-based tools created and used by occupational therapists to assess these risk factors.

Determining which test is more appropriate between Trail Making Test A and B must also be taken into consideration. A systematic review done by Roy and Molnar (2013) found that having a completion time of >180 seconds or three or more errors on the Trail Making Test B typically indicated that a person was more likely to fail an on-road driving assessment. Another study found Trail Making Test B completion time to be significant at differentiating between patients with neurological conditions who passed and who failed the on-road assessment (Holowaychuk et al., 2020). Although Trail Making Test B was shown in that study as a predictive indicator of driving performance for patients with neurological conditions, Trail Making Test A was found in other studies to be a better predictor of driving performance, especially among patients with stroke (Barco et al., 2014). These discrepancies imply that the type of impairment may also dictate which test is more sensitive to predicting driving outcomes.

UFOV™

Although Trail Making Test B may be a better predictor of crash involvement, UFOV™ was shown to be a better predictor of on-road test performance (Classen et al., 2013). UFOV™ is also sensitive to attentional and speed processes (Matas et al., 2014). The different subtests allow assessment of specific cognitive processes such as visual acuity and contrast sensitivity, change detection, processing speed, and crowding.

Determining the correlation between crash involvement and driving risk, as opposed to individual on-road test performance and driving risk would need to be concluded before determining whether to use one test, UFOV™ or Trail Making Test B, over the other. The Trail Making Test B demands other high-functioning skills such as “problem solving, executive function, and working memory, as well as visual scanning, and eye–hand motor control,” and therefore more closely relates to the IADL demands of driving (Friedman et al., 2013). However, the Trail Making tests are typically used to test the fluidity of cognitive abilities with timed components. Although these tests are measuring cognition and speed, one study found that they may not be sensitive enough to discriminate when cognitive impairment has declined to a level that increases driving risk (Dobbs & Shergill, 2013). Both performance-based assessments and driving risk may be necessary as part of a battery of tests for determining driving risk as neither of these tests is performance-based outside of pencil and paper.

Another study tested one assessment from each of the domains of cognitive processing speed, visuospatial abilities, and memory; they found correlations with driving performance were moderate and not one test was wholly conclusive (Anderson et al., 2012). Papandonatos et al., (2015) also found that the Trail Making tests are a good screening tool, but are not precise enough to test cognitively impaired older adults, further demonstrating the need to find a more inclusive battery of tests, rather than relying on the Trail Making tests or even UFOV™

singularly for cognitive determinations. Once again, there is not a single test that measures the multiple variables that driving is dependent upon such as vision, cognition, perception, or physical ability, and therefore, more than one test is needed to determine fitness to drive (Dickerson et al., 2014).

Determining Driving Risk and Fitness to Drive

Determining driving risk is difficult for healthcare professionals without a standardized protocol of tests to follow; often primary care providers are left to make these decisions about fitness to drive (Morgan, 2018). It is imperative that the appropriate, skilled healthcare professional is determining fitness to drive, and with the appropriate screening tool, referrals can be made to the determining professional. As healthcare professionals assess driving risk in older adults, it is important to note the importance of driving as an IADL. The right healthcare professional must be able to find the appropriate balance between promoting and increasing community mobility, while also ensuring safe driving practices are being followed. Thus, the assessments used to determine fitness to drive must be specific and sensitive enough to identify at risk drivers so that the independence of older drivers that are not at risk is not impacted.

The tools currently being used to determine driving risk are not occupation-based. Each assessment independently focuses on a driving skill such as strength and physical fitness, visual acuity and processing, or cognitive and processing speed. None of the tests truly assess the functional performance aspects of these skills, and how they can translate into the occupation of driving as an IADL. The current test most widely used to determine fitness to drive is the BTW assessment (Dickerson, 2013). Although this test is considered to be the best measure of fitness to drive, it requires both a clinical and on-road component that must be performed by a skilled practitioner with the proper equipment and license, of which there are limited numbers

(Dickerson, 2013). Definitions of the BTW assessment vary, so many clinicians use non-standardized on-road assessments to evaluate each at risk driver (Korner-Bitensky et al., 2006). There is also the risk that is associated with the on-road component when the person being assessed has some disability that may be cause for safety concerns. To lessen this risk, proper tests to determine fitness to drive should be performed beforehand, but those tests need to be sensitive and specific enough to differentiate between those who would pass or fail the BTW assessment. As mentioned before, there is a need for a battery of tests that assess the multiple factors that impact driving ability.

Summary

Age-related decline can cause motor, visual, and cognitive deficits that impact driving in older adults. Medically-at-risk adults are diagnosed with medical conditions that can also impair motor, visual, and cognitive skills that impact driving. As driving is an enabling IADL that requires multiple aspects of motor, visual, and cognitive skills to perform, it is important to assess fitness to drive in both older adults and the medically-at-risk.

Motor skills deficits can be related to aging such as stiff joints, loss of joint range of motion, and slower movements. They can also be caused by medical diagnoses such as Parkinson's disease or other motor-impacting diseases like multiple sclerosis, and this can cause difficulty with performing the motor tasks that are required when driving. Typically, modifications can be made to driving techniques or vehicles with adaptive equipment in order to compensate for different motor deficits.

Visual skills deficits such as low vision can be related to aging and impact driving, but there are also medical diagnoses such as age-related macular degeneration, glaucoma, cataracts, and diabetic retinopathy that can impact driving. Visual acuity has not been proven to be a strong enough indicator of driving risk, but visual processing speed is a stronger indicator of driving risk. Education on vision and its impacts on driving can lead to more self-regulatory behaviors while driving, decreasing driving risk.

Cognitive function also declines with age and can be impacted by medical diagnoses such as dementia, stroke, and multiple sclerosis. Visual perception and executive function are impacted by age-related decline, but cognitive processing speed is shown to have the most impact on cognitive function across age and diagnoses. Processing speed has significant correlations with performance of IADLs and slower processing speeds can impact decision

making, which is required in driving. Slowed processing speed was shown to have a stronger correlation with increased driving risk regardless of age. Unlike motor and visual deficits, cognitive deficits in processing speed is less amenable to adaptations to compensate for loss of function, especially among the medically-at-risk population that may not be in a position to remediate their cognitive deficits.

The most predictive tests for determining driving risk, based on the literature, should assess cognitive processing speed. The Trail Making Test B and Trail Making Test A, as well as the UFOV™ contain cognitive processing speed assessment aspects, but multiple studies show that none of these tests is precise enough to be used alone to determine fitness to drive. The BTW assessment is still the golden standard test for determining fitness to drive, but there is a risk during on-road performance that must be considered. If there is a test that can predict fitness to drive, then the risk of the on-road assessment could be decreased. The Vision Coach™ is a tool that assesses cognitive processing speed using a performance-based approach, not just paper and pencil, like the Trails and UFOV™.

Based on the scope of practice for occupational therapy, occupational therapists are highly qualified healthcare professionals to be determining fitness to drive. The Vision Coach™ has the potential to be a reliable and valid assessment tool developed by an occupational therapist for assessing processing speed. It assesses cognitive processing speed by measuring visual reaction time, controlled for age. Thus, the primary purpose of this study will be to determine whether the Vision Coach™ demonstrates adequate sensitivity and specificity to predict fitness to drive and if appropriate cutoff points for determining driving outcome can be established. In addition, the other specific research question includes whether there is a

statistically significant difference of reaction times on the Vision Coach™ between the age groups as well as with the medically-at-risk group.

Chapter III: Methods

Design

A predictive validity design was used to look at the Vision Coach™ reaction times across healthy young, middle-aged, and older adults, as well as a medically-at-risk group. Two difference analyses were performed. A comparison was done of the Vision Coach™ reaction times between the age groups to confirm the establishment norms of Vision Coach™ reaction time among the age groups. Next, a comparison of the medically-at-risk group with the healthy control group of corresponding age was completed. A logistic regression analysis was completed to predict the outcome of a comprehensive driving evaluation (dependent variable) using the Vision Coach™ reaction times (independent variable). While the actual outcomes of a comprehensive driving evaluation include a pass, fail, or a pass-with-restrictions, for the purpose of this analysis, a passing-with-restrictions was categorized as a failing determination.

Participants

There were two target populations, healthy controls and medically-at-risk drivers.

Healthy Controls. The target population of this study was adult drivers in Greenville, North Carolina. Healthy adults were recruited for the study with the inclusive criteria being aged 16 to 90 years and free of any vision or physical deficits that could impair driving ability. Recruiting healthy individuals was done through contacting eligible participants and contacts from previous studies. Eligible volunteers were accepted, and snowballing was used as participants recruited others by word of mouth. Flyers were made and placed around the East Carolina University campus, and advertisements for participants were emailed to the College of Allied Health Sciences to be sent out in the weekly newsletter. Consent was obtained by all participants prior to data collection. An incentive of \$20 in an Amazon gift card was offered.

In addition, data from a previous study collected under the same protocols was also included (UMCIRB 15-000017). This consisted of healthy young adults (N = 51), healthy middle-aged adults (N = 21), and healthy older adults (N = 49) for a total of 114 young adults (ages 16-39 years), 48 middle-aged adults (40-64 years) and 110 healthy older adults (over 65 years).

Medically-at-Risk. The other group of participants composed the medically-at-risk drivers. Data from the Vision Coach™ was already an assessment used to determine fitness to drive, as part of a larger ongoing study (UMCIRB 18-002080). Previously collected for comprehensive driving evaluations of medically-at-risk adults (N = 34) and data collected using this study (N = 113) comprised the medically-at-risk population (N = 147).

Instrumentation

The Vision Coach™ (Donley, 2009) is a large, black, non-glare membrane that is wall-mounted, measuring 50" x 34" and can be adjusted for height (see Appendix C). This tool has multiple settings, and most parameters can be adjusted. There are 120 small light dots concealed in the dark overlay that spontaneously appear during the simulation. This study used the *Full Field 60 task* (FF 60) which is a task in which 60 dots of light appear in 60 spontaneous locations. The dependent variable is the measurement of time, in seconds, it takes the participant to scan, locate, and touch each light as it appears on the screen. One light appears at a time, and it does not disappear until it has been touched by the participant. Once it has been depressed by the participant using a finger or thumb, the light disappears, and another light appears.

Vision Coach™ has been tested and found to be a reliable tool for measuring psychomotor function (Xi et al., 2014). Normative data for healthy individuals across adulthood has been established in previous studies, finding that there were no significant differences based

on gender, height, or wingspan in the Vision Coach™ (Register, 2016; Miller, 2017). One study also found that the participant's position while completing the task, such as sitting or standing, did not produce any significant differences (Miller, 2017). Xi et al. (2014) also established that the learning effect is stabilized after three trials. One study using the Vision Coach™ reported significant changes across age, as healthy adults showed decreased speeds, indicating that the normal ageing process impacts performance on the psychomotor functions (Register et al., 2016). A more recent study has established that visual processing speed as assessed by the Vision Coach™ can differentiate between healthy community-living adults and medically-at-risk adults independently of the medical condition (Penna, 2022). This study also found that Vision Coach™ was able to differentiate between those medically-at-risk adults who “passed” or “failed” a comprehensive driving evaluation using the processing speed reaction times. However, there was only a small number (N = 34) of medically-at-risk participants. Nevertheless, this suggested that the Vision Coach™ may be an appropriate tool to assess processing speed reaction times in relation to determining fitness to drive.

Procedure

Healthy Controls. Once a participant indicated interest, an appointment was set. When a participant arrived for the scheduled appointment, they were given the consent form to read and sign. The participant was then directed to Vision Coach™ and the researcher ensured that the screen was located at a height appropriate for the participant to be able to see and reach all areas of the screen. A practice demonstration was shown with an explanation that the goal of the task is to touch each dot as quickly as possible. The mode of the Vision Coach™ was set to the Full Field 30 task to practice pressing the screen prior to completing the research trials, to ensure participants understood the task. The Vision Coach™ was then set to the FF 60 task. Each

participant was asked to perform the same FF 60 task three times with 30 seconds of rest between each trial following the instructions (see Appendix D). The three trial times were averaged for each participant.

The participant filled out a short questionnaire to collect demographic information and self-reported health status (Appendix E). Once this was completed, the participant concluded their portion of the data collection, and a gift card was distributed to them in payment for their time.

Data Analysis

Data analysis was performed using the average of the three trial times for the Vision Coach™ for both groups, the healthy controls and the medically-at-risk groups. A coefficient of variation was used to measure the variation from the mean for each participant among the three trials. Results of this showed a mean of 6 percent variation, with a min of zero and a max of 20 percent variation of standard deviation to the mean, supporting using the average of the three trials as the outcome measure for reaction time did not impact data analysis.

To answer the age difference, a one-factor ANOVA was used to compare differences in reaction times between the age groups (young, middle, old) of the healthy controls. In addition, a two-factor ANOVA was used to identify differences in reaction times based on driving risk (healthy control vs. medically-at-risk) as well as age across the groups. A logarithm transformation was used on the original Vision Coach™ average time per participant to stabilize the variance and avoid violating the assumption of constant variance for the ANOVA. Finally, a logistic regression was performed to determine the effects of processing speed reaction time on the outcome of a comprehensive driving evaluation. Receiver Operating Characteristic (ROC) curves were created to determine the Area Under the ROC Curve (AUC) when using the Vision

Coach™ as a covariate to predict the outcome of a comprehensive driving evaluation. The ROC curve is a visual measure of how well a binary classification model works, demonstrating varying levels of certainty by plotting sensitivity and specificity across a multitude of cut points. The AUC is an aggregate quantification of the sensitivity and specificity of the clinical test, the Vision Coach™, derived from the ROC curve to identify the validity of the clinical test to predict the outcomes of a comprehensive driving evaluation. Data analysis was performed using the Statistical Packaging for the Social Sciences (SPSS Version 28).

Chapter IV: Results

Demographic Data for Healthy Controls and Medically-at-Risk

Table 1 illustrates the demographic data between the healthy controls and the medically-at-risk drivers. The healthy controls group had a mean age of 49.45 (Standard Deviation (SD) = 21.89), and 72.1 percent were female, while 27.9 percent were male. The medically-at-risk group had a mean age of 62.22 (SD=15.72), and 35.4 percent were female, while 64.6 percent were male. The age range between the groups was similar, with the healthy controls aged 21 to 87 years, and the medically-at-risk aged 16 to 90 years. There was, however, more healthy controls (N = 272) as compared to medically-at-risk (N = 147), with a higher number in the young age group. However, it is typical of the medically-at-risk group to be primarily older adults as older adults have more medical conditions which may require a comprehensive driver evaluation, making this a natural presentation of the data set.

Table 1

Demographics Between Groups

Participants (N = 419)	Healthy Controls	Medically-at-Risk
N (%)	272 (64.9%)	147 (35.1%)
Age, M (SD), Range	49.45 (21.89), 21 – 87	62.22 (15.72), 16 – 90
Age Group Ranges, N (%),		
16 – 39 Young	114 (41.9%)	11 (7.5%)
40 – 64 Middle	48 (17.6%)	61 (41.5%)
65 + Old	110 (40.4%)	75 (51.0%)
Gender, N (%)		
Male	76 (27.9%)	95 (64.6%)
Female	196 (72.1%)	52 (35.4%)

Differences in Reaction Times Between Age Groups of Healthy Controls

Graphical analysis shows the marked difference in reaction times among the age groups of the healthy controls with five (%) outliers (See Figure 1). Table 2 illustrates the means of each age group of the healthy controls. The mean reaction time for the young age group was 44.80 seconds; the middle age group mean was 53.09 seconds, and the old age group mean was 64.40 seconds. Variation of reaction time increased as age increased, with the young age group standard deviation (SD) at 4.19, while the middle age group was 7.72, and the old age group at 8.70. Since the SD was so variable, the average reaction time was transformed using a logarithm transformation (Table 3). This was done to ensure that the ANOVA was performed without violating the assumption of similar variance. These logarithm transformed means were compared using a one-factor ANOVA, and the results of a Tukey's HSD test is illustrated in Table 5.

The one-factor ANOVA revealed that there was a statistically significant difference in reaction times between at least two groups ($F[2, 269] = 256.568, p = <.001$) (Table 4). The Tukey's HSD Test for multiple comparisons found that the mean value of reaction time was significantly different between all three groups ($p = <.001$). The mean score for the young age group ($M = 44.80, SD = 4.19$), the mean score for the middle age group ($M = 53.09, SD = 7.72$), and the mean score for the old age group ($M = 64.40, SD = 8.70$) were each significantly different from the other age groups (Table 5). These results suggest that natural aging causes a decrease in reaction speed to a visual stimulus. Decreased reaction speed can impact older drivers when responding to events that occur while driving such as hitting the brakes and stopping unexpectedly to avoid a crash.

Table 2

Descriptive Statistics for One-Factor ANOVA

95% Confidence Level

Age Group	Mean	SD	Std. Error	Lower Bound	Upper Bound
Young (18–39)	44.795	4.1905	.3925	44.018	45.573
Middle (40–64)	53.090	7.7199	1.1143	50.849	55.332
Old (65+)	64.397	8.7037	.8299	62.752	66.042

Table 3

Descriptive Statistics for One-Factor ANOVA with Logarithm Transformation

Age Group	Mean	SD	Std. Error	95% Confidence Level	
				Lower Bound	Upper Bound
Young (18–39)	3.7978	.09275	.00869	3.7806	3.8150
Middle (40–64)	3.9625	.13670	.01973	3.9228	4.0022
Old (65+)	4.1562	.13280	.01266	4.1311	4.1813

Table 4

One-Factor ANOVA using logAvg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.197	2	3.598	256.568	<.001
Within Groups	3.773	269	.014		
Total	10.970	271			

Table 5

Post Hoc Tests Comparison for Age Effects of One-Factor ANOVA with Logarithm Transformation

Age Group		Mean Difference	Std. Error	Sig.	95% Confidence Level	
					Lower Bound	Upper Bound
Young (18–39)	Middle	-.16467	.02038	< .001	-.2127	-.1166
	Old	-.35842	.01583	< .001	-.3957	-.3211
Middle (40–64)	Young	.16467	.02038	< .001	.1166	.2127
	Old	-.19376	.02049	< .001	-.2420	-.1455
Old (65+)	Young	.35842	.01583	< .001	.3211	.3957
	Middle	.19376	.02049	< .001	.1455	.2420

Differences Between Reaction Times of Healthy Controls and Medically-at-Risk Groups

A graphical analysis of reaction times across age groups between the healthy controls and the medically-at-risk group was conducted (Figure 2). Following this, a two-factor ANOVA was performed to determine if age and driving risk had a significant effect on reaction time. Age was divided into groups of young (16 – 90 years), middle (39 – 64 years), and old (65+ years), while driving risk was determined by whether the participant was in the healthy control group or the medically-at-risk group. Table 6 illustrates the descriptive statistics of the data set, with a range of SD going from 4.19 in the healthy control young drivers, to 16.91 for the medically-at-risk old drivers. The variance of SD among the data set shown in Table 6 violated the ANOVA assumption of similar variance, so the average reaction time was transformed using a logarithm transformation illustrated in Table 7. The two-factor ANOVA and Tukey HSD post hoc test was performed using that variable, logAvg (Table 7 and Table 9). The two-factor ANOVA revealed

that age ($p < .001$) and driving risk ($p < .001$) both had a significant effect on reaction time (Table 8). However, analysis showed that there was not a statistically significant interaction between age and driving risk ($F(2, 413) = .936, p = .393$) on reaction time (Table 8). These results suggest that increased age resulted in significantly slower reaction times and having a medical condition that increased driving risk also resulted in significantly slower reaction times. However, the age effect did not depend upon the driving risk, and the driving risk effect was not dependent upon age.

Table 6

Descriptive Statistics for Two-Factor ANOVA

Driving Risk	Age Group	Mean	SD	95% Confidence Level	
				Lower Bound	Upper Bound
Healthy Controls	Young (18–39)	44.795	4.1905	42.775	46.816
	Middle (40–64)	53.090	7.7199	49.977	56.204
	Old (65+)	64.397	8.7037	62.340	66.454
Medically-at-Risk	Young (16–39)	50.970	9.1037	44.466	57.474
	Middle (40–64)	65.295	15.6538	62.533	68.057
	Old (65+)	78.653	16.9107	76.162	81.144

Table 7

Descriptive Statistics for Two-Factor ANOVA with Logarithm Transformation

Driving Risk	Age Group	Mean	SD	95% Confidence Level	
				Lower Bound	Upper Bound
Healthy Controls	Young (18–39)	3.7978	.09725	3.770	3.826

	Middle (40–64)	3.9625	.13670	3.919	4.006
	Old (65+)	4.1562	.13280	4.127	4.185
Medically-at-Risk	Young (16–39)	3.9173	.17306	3.826	4.008
	Middle (40–64)	4.1559	.20738	4.117	4.194
	Old (65+)	4.3440	.20368	4.309	4.379

Table 8

Tests of Between-Subjects Effects of Two-Factor ANOVA

Dependent Variable: LogAvg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	16.139a	5	3.228	137.108	<.001
Intercept	3716.335	1	3716.335	157862.112	.000
HealthCat	1.573	1	1.573	66.822	<.001
AgeGroup	6.065	2	3.033	128.818	<.001
HealthCat * AgeGroup	.044	2	.022	.936	.393
Error	9.723	413	.024		
Total	6945.451	419			
Corrected Total	25.861	418			

a. R Squared = .624 (Adjusted R Squared = .619)

Table 9

Post Hoc Tests Comparison for Age Effects of Two-Factor ANOVA with Logarithm

Transformation

95% Confidence Level

Group I	Group J	Mean	Std.	Sig.	Lower	
		Difference (I-J)	Error		Bound	Upper Bound
Young (18–39)	Middle	-.202	.028	< .001	-.257	-.146
	Old	-.393	.027	< .001	-.445	-.340
Middle (40–64)	Young	.203	.028	< .001	.146	.257
	Old	-.191	.019	< .001	-.228	-.154
Old (65+)	Young	.393	.027	< .001	.340	.445
	Middle	.191	.019	< .001	.154	.228
Medically-at-risk	Healthy Control	.167	.020	< .001	.127	.207

Predictability of Driving Fitness Using the Vision Coach™

A logistic regression was performed to estimate the probability of passing the comprehensive driving evaluation based upon the average time scored on the Vision Coach™. Table 10 illustrates the classification table of predicted outcomes based on the logistic regression model using the Vision Coach™ times and the observed outcomes of the comprehensive driving evaluation. Using the default cutpoint of 0.5, the model correctly predicted 86.4 percent of the cases, accurately predicting 300 passing cases and 62 failing cases out of 419 total cases. Table 11 illustrates that if the value (in seconds) of the Vision Coach™ time increases with one unit, then the odds of passing the comprehensive driving evaluation are .861 times less likely ($p = .001$). With this information, an ROC curve was calculated for the Vision Coach™ reaction speed times (See Figure 3). The AUC was significant at .905 ($p = .001$, 95% CI = [.875, .935]), and can be seen represented in Table 12. As the AUC is greater than 0.9, the Vision Coach™ is

interpreted as having “Outstanding” diagnostic performance (Mandrekar, 2010). A chart delineating the coordinates of the curve can be found in Appendix F, illustrating the varying points of sensitivity and (1-specificity) along this ROC curve.

Table 10

Logistic Regression Observed vs. Predicted Outcomes and Percentage Correct (n = 419)

		Predicted Outcome		% Correct
		Fail	Pass	
Observed Outcome	Fail	62	40	60.8
	Pass	17	300	94.6
Overall Percentage				86.4

Table 11

Logistic Regression Predicting Likelihood of Passing the On-Road Assessment (n = 419)

Variable	B	S.E	Wald	Sig.	df	Exp(B)
Average Vision Coach™ Time	-.149	.016	91.644	.001	1	.861

Table 12

Area Under the Curve: Test Result Variable is Average Vision Coach™ Reaction Speed Time

AUC	Std. Error	Asymptotic Sig.	95% CI Lower Bound	95% CI Upper Bound
.905	.015	.000	.875	.935

An additional ROC curve was created factoring in average Vision Coach™ time, age, and driving risk, and the AUC was found to increase to 0.962, meaning that adding only age and

whether the client is medically-at-risk further enhances the diagnostic performance (Figure 4).

This could be integral to determining fitness to drive.

Chapter V: Discussion

This study investigated the ability of the Vision Coach™ to accurately serve as a predictor of fitness to drive. This included analyzing Vision Coach™'s processing speed reaction times between groups of healthy adults and medically-at-risk adults across age groups, building upon research previously done by Register (2016), Miller, (2017), and Penna (2022). In completing their thesis research, Register (2016) and Miller (2017) found that gender and physical positioning while using the Vision Coach™ did not impact data outcomes. However, they also found that age has an inverse relationship with processing speed, namely, as age increases, processing speed decreases. We expanded on those results by collecting significantly more data points and confirmed age has a statistically significant impact on visual processing reaction speed times.

In a later study, Penna (2023) collected data on medically-at-risk older adults and found that the Vision Coach™ was able to clearly differentiate between the healthy, community-living adults and the medically-at-risk adults using the visual processing speed reaction times. However, visual processing reaction speed was not significantly different across diagnoses (i.e. dementia, stroke, diabetes, etc.), suggesting this tool could be used universally regardless of the diagnosis for assessing visual processing speed reaction time. While Penna's (2022) results suggested that the Vision Coach™ could be a tool to determine fitness to drive, there was not sufficient data to address the question definitively. This study provides the critical evidence to support the use of visual processing reaction speed using Vision Coach™ as an evidence-based tool for fitness to drive for adults.

The findings of this study clearly demonstrate that there is an age effect on visual processing speed reaction time. The average visual processing speed for the young adults being

approximately 44.8 seconds, versus middle aged adults being 53.1 seconds, and the older adults being 64.4 seconds. The confidence intervals for each age group do not overlap, further demonstrating that the age groups were significantly different in their visual processing speed reaction times, and the older the group, the more time was required to complete the task. This also further supports the early work of Salthouse's (1996) processing speed theory as an important part of age-related cognitive decline. The data shows that increased age leads to slowed processing speed. The data also shows that medical diagnoses can significantly slow processing speed. Increased age and the presence of a medical diagnosis both contribute to slower visual processing speeds, but they act independently of each other. A medical diagnosis at any age can produce slower visual processing speed, so a young adult diagnosed with a medical condition could demonstrate slowed visual processing speed regardless of age. This also means that an older adult without any diagnosed medical conditions will demonstrate slowed visual processing speed. Thus, increased age slows visual processing speed regardless of the presence of a medical diagnosis, and a medical diagnosis can slow visual processing speed regardless of age.

Current research shows that there is no single test appropriate for determining fitness to drive (Dickerson et al., 2014; Dickerson et al., 2019). However, visual processing speed has been shown to be a significant indicator of variance in ability to practice safe driving (Anstey et al., 2012). In addition, Hotta et al. (2018) found processing speed to be more closely related to driving risk regardless of age. Finally, another study found the likelihood of individuals being involved in a motor vehicle crash was increased in those with decreased visual processing speed (Elgin et al., 2012). Thus, using this measure adds an important criterion that will separate those who are fit and unfit to drive.

Previous research done by Wadley et al. (2021) shows that processing speed is strongly and closely correlated with the ability to perform IADLs, including driving, for those with cognitive impairment. This means that processing speed should be an integral factor for determining fitness to drive. The UFOV™ has been hailed as a good screening tool for visual processing speed (Clay et al., 2005; Edwards et al., 2006; Ball et al., 2006; Owsley et al., 1998). Individuals who performed poorly on UFOV™ Subtest 2, a test for evaluating visual processing speed, were found more likely to fail the comprehensive driving evaluation (Classen et al., 2009; Classen et al., 2011). This study demonstrated that the slower the visual processing speed reaction times on the Vision Coach™, the more likely the individual was to fail the comprehensive driving evaluation as well. Supporting visual processing speed reaction time as an indicator for determining fitness to drive, this suggests the Vision Coach™ is an appropriate and valid screening tool to measure these differences in visual processing speed reaction times and may be similar to results of the UFOV™ Subtest 2 (Ball et al., 2006; Edwards et al., 2006; Owsley et al., 1998). Thus, the question emerges which test to use. The UFOV™ Subtest 2 is composed of three separate subtests on a computer, taking approximately 15 minutes to complete, moving quickly through the three types of scenarios in rapid succession. In contrast, the Vision Coach™ measures visual processing speed reaction times with a practice trial and three research trials. It is a simple task that is easy to set up and demonstrate, and it can take less than 5 minutes to complete, gathering all pertinent information to determine visual processing speed reaction times for each participant. Thus, it is a less complex, less time-consuming and tedious test to complete when compared to the UFOV™ Subtest 2. More importantly, the results demonstrate the Vision Coach™ is a valid predictor of performance on a comprehensive driving evaluation, providing the tool to determine cutpoints with which practitioners can determine

when further evaluation is necessary. Utilizing the proper assessment tools will streamline time, energy, and resources when a comprehensive driving evaluation is indicated. As mentioned previously, there is not one assessment that can determine fitness to drive, so ensuring that each assessment is efficient for the participants will only improve and streamline the process. The Vision Coach™ is a more suitable and efficient assessment tool than the UFOV™ Subtest 2.

This study was able to specifically quantify the predictability of the Vision Coach™ in determining fitness to drive. The results showed that the Vision Coach™ is a valid predictor of fitness to drive, meaning that it is capable of predicting whether someone will pass or fail a comprehensive driving evaluation. Using the ROC curve, which is a curve of probability, the AUC of .905 indicates that the Vision Coach™ visual processing speed reaction time model has an approximate 90 percent chance of accurately predicting the outcome of the comprehensive driving evaluation. This means that the Vision Coach™ can be used to assess older adults and medically-at-risk adults to easily and quickly determine those at higher risk for being unfit to drive, those who are likely fit to drive, and those who would need to complete a comprehensive driving evaluation. The Vision Coach™ demonstrates that those adults with very high reaction speed times tend to fail the comprehensive driving evaluation. It is not merely age that affects visual processing speed, and just because older adults have slower processing speed due to the natural aging process, medically-at-risk adults can have greater deficits impacting visual processing speed, and therefore, driving.

Application to Occupational Therapy Practice

As driving is an IADL, it falls directly in the domain of occupational therapy to determine fitness to drive through evaluation (AOTA, 2020; AOTA, 2016). Occupation-based assessments and tools are currently examining driving skills such as motor coordination and

visual acuity, but other than the UFOV™ Subtest 2, visual processing speed is not being measured in driving evaluations (Dickerson, 2013). Since the Vision Coach™ has demonstrated itself as a valid and useful tool for measuring visual processing speed reaction times, it can be used by occupational therapy generalists to determine when a comprehensive driving evaluation is necessary.

Comprehensive driving evaluations typically assess physical abilities such as range of motion, coordination, strength, and postural control, as well as cognition, vision, and attention, which are all necessary for driving (Dickerson & Niewoehner, 2012; Barco et al., 2012, Gillen, 2009). These evaluations are time-consuming and costly for practitioners and patients in a clinical setting as well as an on-road component. Using the Vision Coach™ as a component of the clinical testing for fitness to drive, general practitioners can use the norms to determine when someone would be a good candidate for a comprehensive driving evaluation. The Vision Coach™ is a simple and easy task to perform with a patient, taking only a few minutes to complete, but can assess visual processing speed and determine if there is a need for the comprehensive driving evaluation. The Vision Coach™ can also be used to assess range of motion, strength, praxis, postural control, dynamic and static sitting or standing balance, cognition, attention, bilateral upper extremity coordination, and sequencing, just through clinical observation of the task. These observations along with performance on the Vision Coach™ Full Field 60 task against norms can be used to cut down on the need for comprehensive driving evaluations that may not be necessary.

Not only can the Vision Coach™ be used as a tool to assess visual processing speed reaction time, it can be used as an intervention tool to improve visual scanning as well as processing speed. With its various different settings to specify the field of view size and location,

it can be used to address multiple client performance deficits such as neglect or inattention. The therapist can make the interventions client-centered and grade each task to fit the client's needs by simply changing a setting with the push of a button. Cognition can also be addressed through the ingenuity of the therapist. With varying settings for changing colors of the dots, numbers and letters both uppercase and lowercase appearing randomly in some dots, and varying speed settings, intervention options are endless. This can include, but is not limited to, multi-tasking, attention to task, sustained attention, right/left discrimination, word finding, cognitive organization, and discrimination. Generalist therapists can use the Vision Coach™ to improve these client factors prior to a client attempting a comprehensive driving evaluation.

Driving specialists can use the Vision Coach™ to assess, specifically, visual processing speed reaction times, and this can be compiled alongside other assessments to better determine fitness to drive. Research has clearly shown that visual processing speed reaction time has been closely and strongly correlated with passing or failing a comprehensive driving evaluation. This means that since the Vision Coach™ is an appropriate tool to assess visual processing speed reaction time, it is an easy and efficient tool to add to a comprehensive driving evaluation. Specialists can use the Vision Coach™ reaction speed times to make more sound clinical judgements in regards to fitness to drive. It can also be used as another piece of data to present to a patient or other practitioners to further explain or justify a decision regarding driving fitness.

Future Research

Future research involving the Vision Coach™ should identify the most adequate sensitivity and specificity levels to determine cut points for practitioners. Although this research determined that the Vision Coach™ is a valid tool as a predictor of driving fitness, the optimal cut point was not calculated, since this study only utilized the default of 0.5. Further research

could also be conducted using the UFOV™ Subtest 2 in comparison to the Vision Coach™ Full Field 60 task to determine which assessment tool more accurately predicts fitness to drive. Research should also look beyond the Full Field 60 task to determine if there is comparable assessment of visual processing reaction speed using other tasks such as the Full Field 30 task.

Limitations

To avoid limitations regarding data collection, since the medically-at-risk adults were engaged in this research as part of a larger comprehensive driving evaluation and the healthy controls were just participating in the Vision Coach™ practice trial and three research trials, the same protocols were followed for each group. There may have been a limitation of fatigue for the medically-at-risk group, since the Vision Coach™ portion of the evaluation typically took place after completing two cooking activities for the Assessment of Motor and Process Skills (Fisher, 2006) test. The medically-at-risk participants may have been more fatigued after the AMPS activities, whereas the healthy control group started with the Vision Coach™ trials. To account for this potential for fatigue, rest breaks up to one minute were allowed between trials, and each medically-at-risk adult was allowed a rest period after the AMPS prior to engaging in the Vision Coach™ trials. Due to this, any affect that fatigue played for the medically-at-risk population should be attributed to symptoms related to their conditions, and thus would affect the medically-at-risk population more so than the healthy controls regardless of what order the participants engaged in the Vision Coach™ trials.

An additional limitation to consider is the placement of the random dots on the Vision Coach™ Full Field 60 task. Since the dots appear in random order and in random spots, it can seem that reaction speed is faster on some trials due to convenience of location. There could also have been a learning effect since each participant performed one practice trial and three

additional research trials. These possible changes in visual processing speed reaction times were accounted for by averaging the three trial times together for the final outcome measure.

Averaging the times together could also be a limitation if variation between each of the trial times was vastly different. To determine whether this was the case or not, a coefficient of variation was performed for each participant's three trial times. The average variance was 6 percent, so this was marginal and therefore averaging the three trial times should not have impacted data analysis or the results.

Another limitation would be the variation in the size of the groups, since the healthy control group was gathered by convenience sampling and therefore was larger than the medically-at-risk group. Since the study was assessing visual processing speed reaction time, which is a discrete skill, it is unlikely that the population of healthy controls or medically-at-risk would vary greatly from those of the general population.

Summary

The purpose of this study was to confirm differences in visual processing speed reaction times between age groups as well as differences between healthy adults and medically-at-risk adults using a significantly larger sample size of participants. The results demonstrate that as age increases, visual processing speed reaction time is slower. The results also show that regardless of age, being medically-at-risk significantly impacts how quickly an individual can respond or react to a visual stimulus. This study also demonstrates that the Vision Coach™ can assess visual processing speed reaction times and use this to accurately predict whether an individual will pass or fail a comprehensive driving evaluation 90 percent of the time. This makes the Vision Coach™ a valid and appropriate tool for occupational therapist generalists to assess whether

clients may need further testing with a comprehensive driving evaluation, and it can serve as a quick and easy tool for specialists to assess fitness to drive.

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APPENDIX A: IRB APPROVAL LETTER

10/14/23, 11:50 AM

epirate.ecu.edu/App/sd/Doc/0/9ISEAGGVNO8UQ7S1LAIPOLIG00/fromString.html



EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284**
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: [Anne Dickerson](#)
CC:
Date: 8/19/2022
Re: [UMCIRB 22-001064](#)
Driving assessment tools

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 8/18/2022. The research study is eligible for review under expedited category # 4. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;
2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);
3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;
4. Submission of a final report application to the UMCIRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and
5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

APPENDIX B: IRB STUDY IDENTIFICATION INFORMATION

East Carolina University

Print
Close

Date: Friday, August 19, 2022 8:57:03 AM
View: 1 - Study Identification Information

Study Identification Information

This is the first step in your Human Research Application. You will automatically be guided to the appropriate page views needed to complete your submission. If a question is not applicable to your study, you may state this as your response. Please read the help text located on the right side of the page throughout this application.

1.0 * Study Name (Short):
Driving assessment tools

2.0 Study Name (Long):
Collection of data for norms of assessment tools

3.0 * Summary of Research in Lay Terms:
More normative data is needed for the Vision Coach (TM).

The Vision Coach is a lighted electronic board with lighted dots that appear in patterns that are programmed. We will be collecting normative data on the full field (whole board) for 60 dots. We will have one practice with about 30 dots and then 3 trials.

We will collect also collect data on the UFOV(TM), which is a trade mark assessment tool that measures processing speed and useful field of vision (or scanning area). It is a standardized evaluation using three programmed tests that measure visual memory and processing speed. We will collect it on normal adults to compare to these two new assessments.

The importance of this study is to get normal data information on processing speed and scanning activity. We are currently observing individuals with medical conditions on this task for determination of fitness to drive. However, it is not clear how the performance of a normal volunteer appears, thus we need to gather data from a wide range of ages.

The overall purpose is to develop the Vision Coach as a screening tool for driving risk or potential problems with fitness to drive. It only takes about 5-10 minutes to do three trials of scanning and indicate the time of visual processing. In contrast, the UFOV takes 20-30 minutes, but it has much research behind it. We need to do both so we can show concurrent validity as well as get more data for the Vision Coach, so we can do cut off scores (receiving operating curve analysis).

Data will be collected on mostly healthy young and middle age adults, as we have some data on older adults and some on college age adults. All participants will be community healthy controls.

4.0 * Principal Investigator:
Anne Dickerson
Principal Investigator IRB Certification Renewal Deadline:6/14/2024
Principal Investigator CV/Resume: [DickersonA ECU CV August 2018.docx\(0.01\)](#)

5.0 Faculty Investigator (Serving as the responsible individual in the oversight of the research study when the PI is a student, resident, fellow or visiting faculty.)
Faculty Investigator IRB Certification Renewal Deadline:
Faculty Supervisor CV/Resume:

6.0 Study Coordinator or Contact Individual:
Study Coordinator IRB Certification Renewal Deadline:
Study Coordinator CV/Resume:

7.0 Contact Individual(s) (if different from Study Coordinator or Principal Investigator):

Last Name	First Name	Organization Profile	IRB Certification Renewal Deadline	CV/Resume
There are no items to display				

8.0 Sub-Investigators:

Last Name	First Name	Organization	Profile	IRB Certification Renewal Deadline	CV/Resume
Denny	Meagan	Occupational Therapy, Department of	Meagan Denny's Profile	8/12/2024	
DuCharme	Alec	Occupational Therapy, Department of	Alec DuCharme's Profile	8/30/2024	

APPENDIX C: VISION COACH™ BOARD



Vision Coach™ with wall mount from Perceptual Testing, Inc. Website.

APPENDIX D: VISION COACH™ PROTOCOL

1. Inform the participant:

“The Vision Coach™ is a visual-motor tool that therapists use to measure visual and processing skills. There will be 60 lights that appear on the screen, one at a time, each disappearing once it has been touched. The goal will be to touch each light dot as quickly as possible.”

2. Ask the participant:

“You will be performing a practice round followed by 3 trials. Would you prefer to sit or stand while you do this?”

3. Once the participant identifies their preferred position, adjust the wall-mounted board so the participant can easily reach from the top to the bottom of the board.

4. Instruct the participant: “You will have a practice round to touch the dots, this score will not be counted in the data collection. Scan the board and touch each dot, you can use both hands.”

5. Set the task for Full Field, using the control panel in the lower right corner, press the “Start” button, and have the participant practice touching the dots on the screen.

6. Ask the participant if they are comfortable with the instructions and if they are ready to begin the trials.

7. Set the Vision Coach™ interactive light board to the Full Field 60 setting using the control panel on the bottom right corner of the board. The setting will appear on the upper right corner of the board once it is set.

8. Press the “Start” button.

9. Record the time displayed on the upper right corner of the board at the end of the trial.

10. Allow the participant 30 seconds of rest before the next trial.

11. For Trials 2 and 3, repeat steps 7 through 10.

APPENDIX E: DEMOGRAPHIC SURVEY

What is your gender?

- Male (1)
- Female (2)
- Other (3)

What is your age?

- Under 18 (1)
- 18 - 34 (2)
- 35 -64 (3)
- 65 + (4)

APPENDIX F: COORDINATES OF THE ROC CURVE

Coordinates of the Curve

Test Result Variable(s): Avg Vision Coach™ Time

Positive if Greater Than or Equal To ^a	Sensitivity	1 - Specificity
35.667	1.000	1.000
36.833	1.000	.994
37.333	1.000	.991
37.833	1.000	.984
38.333	1.000	.978
39.000	1.000	.975
39.500	1.000	.972
40.000	1.000	.965
40.500	1.000	.956
40.833	1.000	.943
41.167	1.000	.937
41.500	1.000	.918
41.833	1.000	.893
42.167	1.000	.886
42.500	1.000	.864
42.833	1.000	.849
43.167	1.000	.836
43.500	1.000	.833
43.833	1.000	.817
44.167	1.000	.811
44.500	1.000	.792
44.833	1.000	.770
45.167	1.000	.757
45.500	1.000	.741
45.833	1.000	.738
46.167	1.000	.729
46.500	1.000	.722
46.833	1.000	.716
47.167	1.000	.703
47.500	1.000	.694
47.833	1.000	.681
48.167	1.000	.672

48.500	1.000	.653
48.833	1.000	.640
49.167	1.000	.634
49.500	1.000	.615
49.833	1.000	.609
50.167	1.000	.603
50.500	1.000	.574
50.833	1.000	.546
51.167	1.000	.524
51.500	.990	.514
51.833	.990	.505
52.167	.990	.502
52.500	.990	.486
52.833	.990	.476
53.167	.990	.467
53.500	.990	.442
53.833	.990	.435
54.167	.980	.432
54.500	.980	.420
54.833	.980	.410
55.167	.971	.404
55.500	.961	.394
55.833	.961	.385
56.167	.961	.379
56.500	.961	.372
56.833	.951	.366
57.167	.941	.356
57.500	.912	.341
57.833	.902	.338
58.167	.902	.328
58.500	.902	.325
58.833	.882	.322
59.167	.882	.319
59.500	.873	.315
59.833	.873	.300
60.167	.863	.297
60.500	.863	.290
60.833	.843	.284

61.167	.843	.274
61.500	.843	.265
61.833	.843	.249
62.167	.833	.246
62.500	.824	.240
62.833	.824	.237
63.167	.814	.233
63.500	.814	.227
63.833	.804	.218
64.167	.794	.218
64.500	.784	.199
64.833	.775	.189
65.167	.765	.189
65.500	.755	.180
65.833	.755	.174
66.167	.745	.155
66.500	.745	.151
67.000	.745	.142
67.500	.735	.132
67.833	.716	.129
68.167	.716	.117
68.500	.716	.114
68.833	.696	.104
69.167	.686	.101
69.500	.667	.085
69.833	.657	.079
70.167	.637	.069
70.500	.627	.063
70.833	.618	.060
71.167	.618	.057
71.667	.618	.054
72.333	.608	.054
73.167	.608	.047
73.833	.608	.044
74.167	.598	.041
74.500	.588	.038
75.000	.578	.038
75.500	.578	.035

76.000	.578	.032
76.500	.578	.028
76.833	.578	.025
77.167	.559	.025
77.500	.549	.022
77.833	.510	.022
78.167	.500	.019
78.500	.461	.019
78.833	.422	.019
79.167	.422	.013
79.667	.402	.013
80.333	.392	.013
80.833	.382	.013
81.333	.373	.006
81.833	.353	.003
82.167	.324	.003
82.500	.314	.003
83.000	.314	.000
83.833	.294	.000
84.500	.284	.000
84.833	.265	.000
85.167	.245	.000
85.500	.235	.000
86.833	.216	.000
88.333	.206	.000
89.167	.196	.000
90.333	.186	.000
91.167	.176	.000
91.667	.167	.000
92.167	.147	.000
92.667	.137	.000
93.667	.127	.000
94.833	.118	.000
96.667	.098	.000
100.000	.088	.000
104.500	.078	.000
107.500	.069	.000
110.333	.049	.000

114.833	.039	.000
124.833	.029	.000
134.667	.020	.000
137.333	.010	.000
139.000	.000	.000

The test result variable(s): Avg has at least one tie between the positive actual state group and the negative actual state group.

a. The smallest cutoff value is the minimum observed test value minus 1, and the largest cutoff value is the maximum observed test value plus 1. All the other cutoff values are the averages of two consecutive ordered observed test values.

Figure 1

Differences in Reaction Times Between Age Groups of Healthy Controls

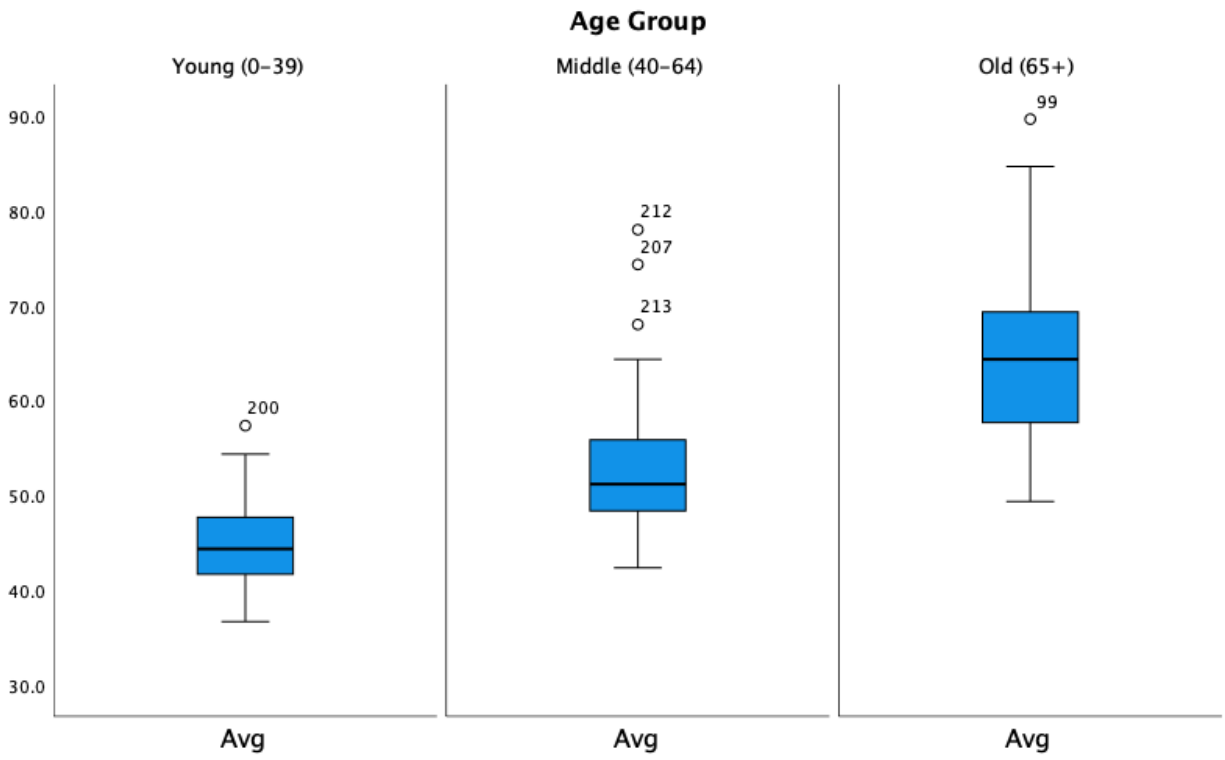


Figure 2

Differences in Reaction Times Among Age Groups Between Healthy Controls and Medically-at-Risk

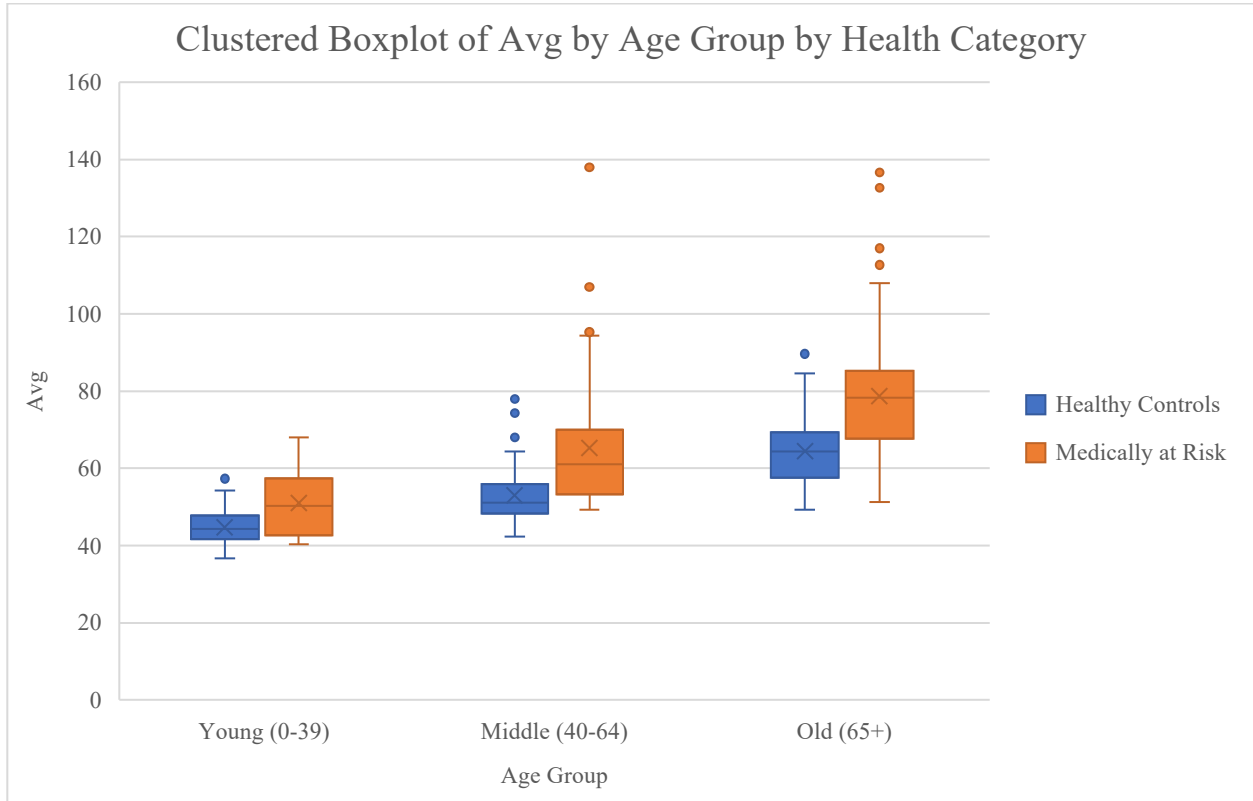


Figure 3

ROC Curve for Average Vision Coach™ Reaction Speed Time

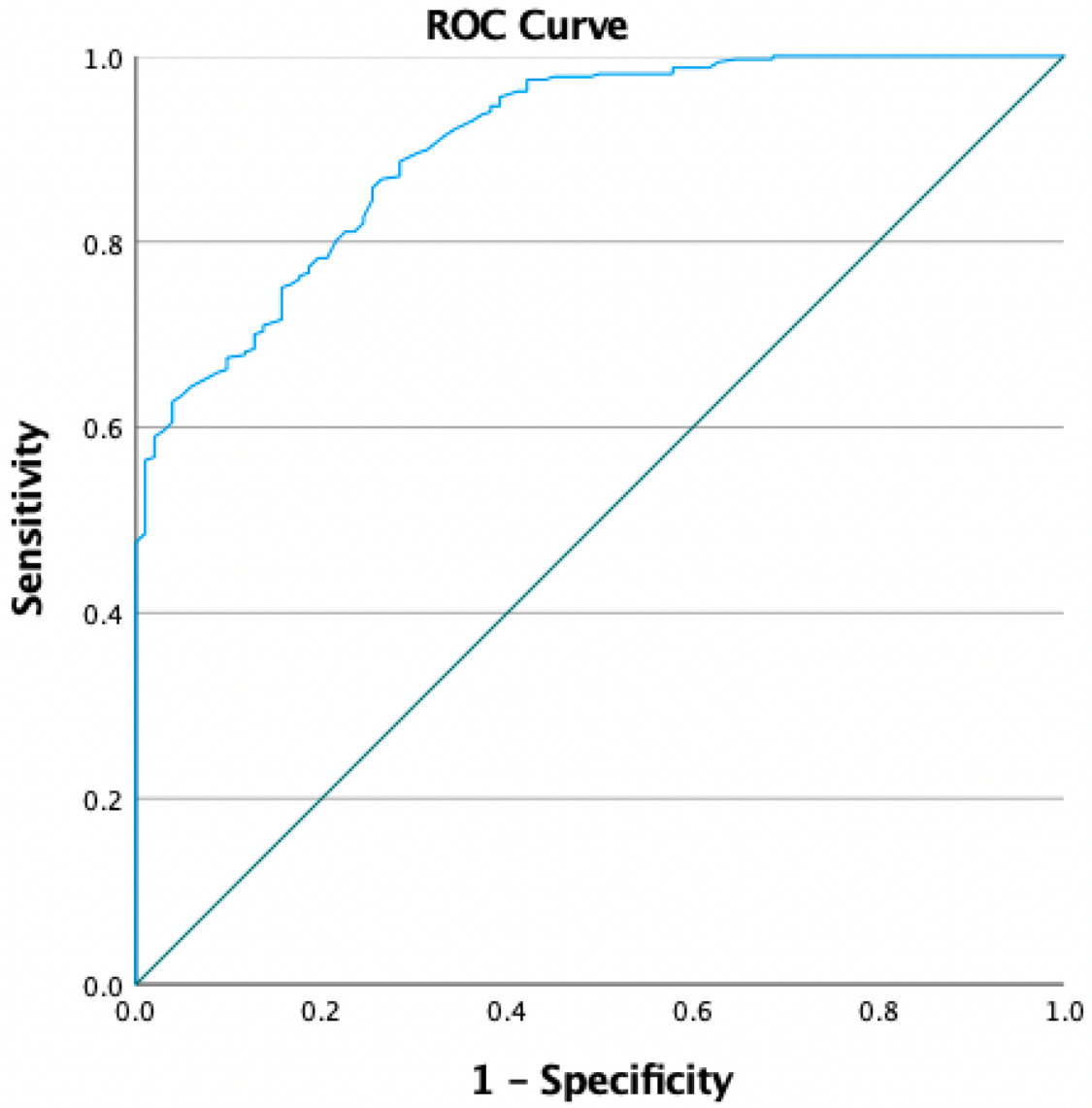


Figure 4

ROC Curve for Average Vision Coach™ Reaction Speed Time, Age, and Driving Risk

