EXAMINING MULTI-TASKING ABILITY ON AN INTERACTIVE DRIVING SIMULATOR TASK TO DIFFERENTIATE BETWEEN FIT AND UNFIT DRIVERS

By

Alec J. DuCharme

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Director of Thesis: Dr. Dickerson

Major Department: Occupational Therapy

ABSTRACT

Rationale: Driving is an important, complex instrumental activity of daily living (IADL) with one of the most important skills being able to multitask. Multitasking is a skill assessed by few standardized assessments. The most well-established measures, while there is some literature linking them to fitness to drive, have no resemblance to driving. Interactive driving simulators present an opportunity to function as an alternative assessment of multitasking that bears a greater resemblance to driving. **Purpose:** The purpose of this study was to examine the use of the DriveSafety™ interactive simulator and a functional object detection (FOD) protocol as an assessment of multitasking. The goal was to answer the questions: 1) is the performance of individuals on a driving-simulator assessment of multitasking correlated with their fitness-to-drive, and 2) does the performance of individuals on a driving-simulator assessment of multitasking differ between medically at-risk and healthy controls? **Methods:** Data were collected from a group of medically at-risk adults (N=124) and a group of healthy control adults (N=131) from the DriveSafety™ simulator. These data were used as a measure of participants' multitasking abilities. Data on fitness to drive classification for the medically at-risk adults was determined with a comprehensive driving evaluation. Simulator outcomes were compared both between medically at-risk and healthy control participants and between fit to drive and unfit to drive participants. **Results:** Chi-square analyses found a significant difference ($p<0.0001$) in simulator performance between fit to drive and unfit to drive individuals. Chi-square analyses also found that there was a significant difference ($p<0.0001$) in simulator performance between medically at-risk and healthy control individuals. **Conclusions:** Differences in simulator performance between the medically at-risk and healthy control groups were consistent with the available literature, helping to validate the driving simulator protocol as an assessment of multitasking ability. Furthermore, the simulator results being closely linked to fitness to drive means that occupational therapists could use this assessment to inform their recommendations regarding fitness to drive and/or whether it may be appropriate to see a more skilled occupational therapist driving rehabilitation specialist.

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Alec J. DuCharme

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Director of Thesis: Anne E. Dickerson, PhD, OTR/L, SCDCM, FAOAT, FGSA

Thesis Committee Members:

Lynne F. Murphy, EdD, OTR/L

Qiang Wu, PhD, PStat®

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Introduction

Occupational therapy is the use of an individual's, group's, or population's everyday activities, or occupations, to both improve participation or make participation possible (American Occupational Therapy Association [AOTA], 2020). Occupations are defined as the things that people do, both individually and as groups, which take their time and give their life a meaning and purpose (AOTA, 2020). Occupations can all fall into one of nine different categories: activities of daily living (ADLs), instrumental activities of daily living (IADLs), health management, rest and sleep, education, work, play, leisure, and social participation (AOTA, 2020). Thus, as an IADL, driving and community mobility is within the scope of occupational therapy practice (AOTA, 2020).

Driving is an especially important and valued IADL for older adults because it helps them maintain their independence and stay active in their communities (Greene & Smith, 2019). In fact, in a study of individuals recovering from stroke, it was concerned the most important IADL (Dickerson, Gaudy, & Reistetter, 2013). About 85% of people 60 and older still drive, demonstrating further the importance of driving as a method of mobility to older adults (Pristavec, 2018). Older adults who drive more are the most likely to maintain high levels of social participation through visiting friends and/or family as well as participate in leisure activities, go to religious services, and participate in organized events (Pristavec, 2018). Participation in these sorts of activities through later stages of life is beneficial to the mental and physical health of an individual over time (Pristavec, 2018). Although driving is important for older adults to engage in different areas of occupation and despite the precautions many older adults take, when in a crash, the risk of being injured increases due to frailty and fragility (Pitta et al., 2021).

In addition to increased risk of injury, as age increases, processing speed and overall multitasking ability are shown to decrease with age (Lord et al., 2018; Murman, 2015; Salthouse, 1996; Svetina, 2016; Wechsler et al., 2018). Regardless of aging, medical conditions with neurological effects can also impact processing speed and multitasking ability (Gale et al., 2018; Lo Coco et al., 2016; Lord et al., 2018; Khellof, 2019; Knight-Greenfield et al., 2019; Murman, 2015; Vargo, 2011). When processing speed and multitasking ability are decreased, driving performance may decrease because driving relies heavily on these skills to attend to and execute many things at the same time or in quick succession (Aksan et al., 2014; Anstey et al., 2012; Classen, Wang, Crizzle, et al., 2013; Cochran & Dickerson et al., 2019; Dickerson et al., 2011; Dickerson & Bédard, 2014; Galski et al., 1998; Michon, 1985). If these skills are affected by age or a medical condition, then it may be appropriate to do consider getting a fitness to drive evaluation.

Occupational therapy practitioners are well positioned to be involved in this process because they can understand and recognize the individual elements and demands of an occupation, including what skills an individual would likely require to successfully engage and participate in the occupation of driving (AOTA, 2020). In fact, occupational therapists are often involved in driver screenings and evaluations (Dickerson et al., 2011; Dickerson et al., 2019). This involves using a series of assessment tools and, in some cases, a behind-the-wheel driving test to determine fitness to drive (Dickerson et al., 2011; Dickerson et al., 2019). Thus, it is important for occupational therapy practitioners to recognize, use, and understand the validity and reliability of assessment tools and when determining fitness to drive, the sensitivity and specificity of tools used for screening and assessment of driving fitness.

Due to the importance of processing speed and multitasking for driving, cognition appears to be a frequently assessed factor, behind assessments of vision and physical factors like strength and range of motion (Dickerson, 2013). There is a large variety of assessments, especially of cognition, being used in driving evaluations (Dickerson, 2013). Fields and Unsworth (2017) and Dickerson (2013) found the most used assessment tools that an occupational therapist may use to evaluate fitness to drive are the Trail Making Test, Part A and Part B - Trails A and Trails B (Reitan, 1958), Motor-free Visual Perception Test (MVPT) (Colarusso & Hammill, 1972), and the Clock Drawing Test (Dal Pan et al., 1989). Driving simulators, by comparison, are a tool used significantly less frequently in driving evaluations (Dickerson, 2013).

Studies have linked behavior and performance on a driving simulator to both on-road behavior and to other psychometrically valid assessments (Bella, 2008; Bédard, 2010). Much of the current literature uses a simulator scenario modeled from a real-world place or scenario (Bella, 2008; Bédard, 2010; Lee et al., 2003). Lee & Lee (2005) assessed discrete skills (e.g. working memory, multitasking) with multiple different contrived levels on a driving simulator and found a connection between performance on some levels and traffic violations committed over a three-year time period. More research is needed to validate different simulator setups and protocols for assessments of driving and driving-related skills.

Definitions

Processing speed: “how fast a person executes mental operations in order to complete a task” (Ticha et al., 2023).

Multi-tasking: performing two or more tasks at the same time (Madore & Wagner, 2019)

Fitness to drive: “a driver characteristic or a description of a driver, defined by the absence of any functional (sensory-perceptual, cognitive, or psychomotor) deficit or medical condition that significantly impairs an individual’s ability to fully control the vehicle while conforming to the rules of the road and obeying traffic laws, or that significantly increases crash risk” (Transportation Research Board, 2016).

Comprehensive driving evaluation: “a complete evaluation of an individual’s driving knowledge, skills, and abilities by a healthcare professional that includes 1) medical and driving history; 2) clinical assessment of sensory-perceptual, cognitive, or psychomotor functional abilities; 3) on-road assessment, as appropriate; 4) an outcome summary; and 5) recommendations for an inclusive mobility plan including transportation options” (Transportation Research Board, 2016).

Literature Review

Driving Framework

According to Michon's Hierarchy of Driving Behavior there are three categories of driving behaviors (Michon, 1985). The highest level is the strategic level, which includes determining the trip destination, route, considering benefits and risk, choosing a mode of transportation, wayfinding, and navigation. The tactical level, at midlevel, encompasses adapting to the environment by avoiding obstacles, negotiating traffic, responding to weather, and/or deciding when and where to turn. Finally, the lowest level of driving, the operational level, includes the physical elements of driving like turning the steering wheel, pushing the pedals, shifting gears, and more which are done automatically (i.e., riding a bike) to execute the decisions made at the tactical level (Cochran & Dickerson et al., 2019; Transportation Research Board, 2016).

Dickerson and Bédard (2014) outlined the different person factors that are important to consider at the three levels of driving. At the strategic level people must have an awareness of their physical state to properly plan, have the cognitive ability to plan and organize the steps to complete the task and reach their goal or destination, emotional awareness to account for anxiety or other emotions that could affect their driving, and have proper insight to evaluate their physical and mental abilities to successfully carry out their plan. At the tactical level people must be able to make necessary adjustments to accommodate for their physical limitations, use their cognitive abilities to evaluate the environment and make the appropriate decisions or adjustments within seconds, and be able to regulate their emotions in potentially stressful situations. At the operational level people must have the physical abilities to carry out the physical demands of operating a vehicle quickly by responding to an action without having to think about it

(Dickerson & Bédard, 2014). Both the strategic and tactical levels of driving involve cognition, but only the tactical level is time limited. This means that an individual's processing speed is vital. Additionally, multiple tactical and operational demands are always present while driving. For example, to avoid a pothole (tactical) while avoiding another car on the road coming the other direction (tactical) a person may have to decide how far to move the car to the left while staying in their lane (tactical) by turning the steering wheel (operational) and hitting the brakes (operational) all while keeping attention on the other car and making rapid decisions of where to move based on its movements (tactical). This is a simple example of the ever-present demands while driving and demonstrates the importance of multitasking to be safe behind the wheel.

Processing Speed, Multitasking, and Driving

Driving is a complicated IADL that requires and is influenced by a variety of necessary skills to safely and effectively complete (Dickerson et al., 2011). Cognitive abilities, especially processing speed and multitasking, are at the forefront of the skills necessary to safely drive an automobile. Galski et al. (1998) reinforces the ideas behind Michon's Hierarchy of Driving Behavior, stating that driving requires an understanding of not only how to maneuver the automobile, but also understanding of the rules of the road, navigation from one place to another by memory or while paying attention to directions, identifying landmarks, scanning the environment for hazards, and more. The variety of challenges and of skills needed to overcome those challenges mean intact multitasking ability and processing speed is essential. While multitasking is a frequently used word which means simply performing equal to or greater than two tasks at the same time, it is widely believed that true multitasking is impossible (Madore & Wagner, 2019). Madore and Wagner (2019) go on to explain that the structure and function of the brain lead it to be adept at focusing on a single task at once, but it can rapidly switch between tasks. In this way, multitasking and processing speed are highly connected, because faster processing speed allows an individual to alternate attention more quickly and successfully to complete multitasking. This was shown in a study which found that higher processing speed is predictive of on-task (multitasking) safety error reduction independent of factors like age, disease, or even overall cognitive function (Aksan et al., 2014). This is important because it shows that processing speed alone, independent of other types of cognitive functioning, is an important factor in whether an individual can safely drive. Unfortunately, an individual's processing speed and multitasking skills are often affected by typical aging.

Normal Aging Changes

The processing speed and multitasking skills required to drive are not static within individuals over time. These skills are developed over time but, more importantly when it comes to driving, they are also slowly lost as people age (Salthouse, 1996). Reaction time is an indicator commonly used to evaluate processing speed, and research has shown that simple reaction time gets progressively slower after reaching 30 years old and continues to decrease, but even more sharply, after reaching 60 years old (Salthouse, 1996). The difference age makes in processing speed is even more evident in completing more complex tasks than simple reaction time. These changes may be due to the structure of the brain being altered with age. The frontal and prefrontal cortex specifically are linked to executive function, and damage to myelin over time or loss of axons while aging can reduce someone's ability to take in sensory information and use it to make evaluate situations and make decisions (Lord et al., 2018).

The idea of changes in processing-speed being the reason for age-related differences was looked at in Salthouse's landmark 1996 paper. In the paper two main theories are outlined. One is that when processing speed slows down there is not enough time to fully process the information and respond, which is called *limited time*. The other is that when processing speed slows the things a person was able to process may have changed by the time, they are able to process the rest, which is called *simultaneity*. Driving requires precise performance of many operations, and the issue of limited time means that a person with diminished processing speed can no longer fully perform the operations on time. The issue of simultaneity applies because of driving's high demand for multitasking abilities to read and respond to many elements of the environment simultaneously (Galski et al., 1998).

Selective and divided attention are important aspects of multitasking that are in many ways connected to processing speed. The clearest changes in attention that come with age are seen in tasks such as selective or divided attention (Murman, 2015). Murman defines selective attention as "the ability to focus on specific information in an environment while at the same time ignoring irrelevant information," and divided attention as "the ability to focus on multiple tasks simultaneously, such as walking an obstacle course and answering questions." Performance on tasks associated with these more complex attentional aspects declines over time with age. This is consistent with decreasing processing speed that accompanies aging. On simple attentional tasks with less demand for multitasking, however, performance is more consistent through the span of age and preserved through older age (Murman, 2015).

Svetina (2016) tested reaction times of participants between the ages of 20 and 80 while they participated in a divided attention driving task. Combining these elements of multitasking revealed that, consistent with the studies showing decreased performance in the areas of processing speed and complex attention with age, mean reaction time increased with age (Svetina, 2016). Interestingly, not only did the mean reaction time increase with age, indicating a performance decrease, but the variability of performance also increased. This increase in variability was so strong that the highest performing older participants did equally as well if not better than some of the younger drivers (Svetina, 2016). This is a critical point in terms of driving and age-related changes. Specifically, that age is not the best measure of driving ability, as everyone ages differently (Dickerson et al., 2019; Hollis et al., 2013).

Wechsler and colleagues (2018) further expand on how multitasking truly works in everyday life. They argue that multitasking is an "ongoing orchestration of task switching and dual-tasking." Traditionally, multitasking has been researched using paradigms that focus only on one or the other, but their paradigm used driving as a more realistic approximation of how multitasking truly presents itself. Their research shows that when presented with different tasks, requiring them to multitask more while using the driving simulator, the performance of people of all ages was impacted. In fact, they found that only one driving parameter was found to be significantly different between young and old. They hypothesize that the lifelong experience of older people may make up for the change in processing speed and multitasking ability they have when engaging in a familiar IADL like driving, or a close approximation of it like driving on a simulator (Wechsler et al., 2018).

The one parameter that was found to be significant was the loading task 'typing' which asked the participants to type on a keypad near the steering wheel. The researchers estimate that this task is like many tasks done when driving like adjusting the radio, rolling windows up and down, and more, and therefore the age differences in this category could be important. There were significant differences between age groups for other variables (e.g., average speed, speed variability, and movement of the car side-to-side in the lane). Older individuals in the study also saw lower scores on the memory task (Wechsler et al., 2018). This research demonstrates that factors outside of processing speed and multitasking ability may have the ability to confound results if not properly controlled. It also shows, however, that there were significant differences based on age in the parameter that likely most closely mirrored the actual process of driving in real life – the one requiring a higher level of multitasking. While these studies show the effects of age on healthy controls, the presence of medical conditions can also have a significant affect on the skills of multitasking and processing speed.

Medical Conditions That Affect Cognitive Abilities and Driving

Despite known decreases in processing speed, divided attention, and selective attention as an individual gets older, age alone is likely not sufficient to predict driving ability (Dickerson et al., 2019; Hollis et al., 2013). This is evidenced by the fact that those aged between 90 and 97 on average had no greater risk of driving than those aged between 80 and 87, as both age groups made similar errors at similar rates (Hollis et al., 2013).

Even though age alone is not necessarily predictive of driving ability, it has been heavily linked with medical conditions that affect driving performance, that is, with increased age, there are increased medical conditions (Carr & Ott, 2010; Dickerson, Schold-Davis, & Carr, 2018). Many different factors and diagnoses have been associated with causing cognitive issues that may affect driving ability. Common conditions closely associated with age include stroke, dementia, Parkinson’s disease, and mild cognitive impairment all have the possibility to cause cognitive impairments (Murman, 2015). Occupational therapists work with people with a wide variety of diagnoses, and the most prevalent neurological conditions include traumatic brain injury, stroke, and dementia among others (Rao, 2012).

Traumatic brain injuries can be suffered at any age and are responsible for over 50,000 deaths in the United States per year (Vella et al., 2017). In the United Kingdom it is the leading cause of death and disability in the under 40 age group (Khellaf et al., 2019). Traumatic brain injury involves a change in brain structure or function. The specific changes to cognitive abilities are dependent on the specific area where brain structures were damaged by either the primary or secondary injury (Khellaf et al., 2019). Skills necessary for driving may be affected especially if the frontal cortex is affected as it is necessary for executive function (Lord et al., 2018).

Strokes can occur at any age, but only about 10%-15% of strokes occur in young adults (Smajlović, 2015). This indicates that the risk for stroke increases with age. There are many kinds of strokes, but certain kinds can affect areas of the brain important for executive function like the frontal lobe (Knight-Greenfield et al., 2019). In fact, stroke is now being recognized as a greater contributor to cognitive impairments and has been connected to a greater risk of developing certain kinds of dementia (Lo Coco et al., 2016).

Dementia is a classification of disorders that cause a decline in cognition which interferes in an individual's life. The most common kind of degenerative dementia is Alzheimer disease (Gale et al., 2018). Only 5% of those with Alzheimer disease are below the age of 65, indicating risk of developing these increases greatly with age (Gale et al., 2018). It can lead to forgetfulness and change in personality, but in some cases can also affect behavior, visuospatial processing, or language abilities (Gale et al., 2018). Other kinds of dementia, such as Frontotemporal Lobar Degeneration have a greater effect on the frontal lobe and can lead to decreased executive function (Gale et al., 2018). Furthermore, Jacobs et al. (2017) explains that individuals with neurodegenerative disorders, including dementias, were found to have impairments on all levels of driving from Michon's Hierarchy. The most common errors were made in the tactical level (Jacobs et al., 2017), a category where processing speed and multitasking skills are necessary. Individuals with dementia may also see a decline in the strategic level. As driving is an overlearned skill, individuals may operate the vehicle appropriately, but find themselves lost even in familiar areas while driving (Dickerson, 2014).

Often, before developing dementia, individuals will experience a stage in between "normal" cognition and cognition impaired sufficiently to be classified as dementia called mild cognitive impairment (MCI). To be classified as having MCI an individual's activities of daily living and typical cognitive functioning must be intact, however their memory must be impaired (Petersen et al., 2001). If an individual is found to have MCI it is important to closely monitor~~y~~ their cognitive abilities and function in their daily lives because they are at significantly greater risk of developing dementia compared to a person with intact cognition (Petersen et al., 2001). Even with only an MCI diagnosis, given the complex nature of driving, an individual may begin to lose their ability to safely operate a motor vehicle.

In sum, as an individual's processing speed and multitasking skills decrease with age and/or as they develop medical conditions, it may be appropriate for them, their caregiver, or their primary care provider to seek the opinion of an occupational therapy practitioner regarding their driving ability.

Occupational Therapists' Role in Driving Evaluation

The Occupational Therapy Practice Framework: Domain and Process – 4th Edition, or OTPF-4, lists driving and community mobility as an instrumental activity of daily living (AOTA, 2020). Evaluation of occupational performance is part of an occupational therapist's process as described in the OTPF-4. Thus, it is part of the occupational therapy provider's scope of practice to evaluate performance and ability to drive. Considering Michon's Hierarchy of Driving Behaviors along with Dickerson's and Bédard's (2014) work connecting person factors with each level of driving, occupational therapists can consider the client's abilities in all the driving-associated person factors in an evaluation to decide about the client's ability to drive (Dickerson & Bédard, 2014).

There are multiple levels of driving evaluation: screening and full driving evaluation. A screening can look at driving risks associated with specific conditions or medicines, vision changes, cognition, sensory function, or motor function and help to determine the next steps the driver should take (Lane et al., 2014). A screening can be used often independently of any health care system, or as requested by a healthcare provider, but only serve to indicate whether there is a need for further, more formal evaluation, a comprehensive driving evaluation (Dickerson et al., 2011).

A comprehensive driving evaluation is carried out by an occupational therapist-driving rehabilitation specialist (OT-DRS), and evaluates the individual's knowledge, skills, and abilities related to driving. It will look at both the medical and driving history of the individual, assess their sensory-perceptual, cognitive, and psychomotor abilities, and include an on-road assessment/behind-the-wheel (BTW) portion if deemed necessary (Dickerson et al., 2011; Dickerson et al., 2019; Transportation Research Board, 2016). The comprehensive driving evaluation results in an outcome summary and recommendations for community mobility going forward (Transportation Research Board, 2016). OT-DRSs have numerous assessment tools to assist in making their final recommendation, and there is great inconsistency in the tools used between specialists (Dickerson, 2013). However, there are few that have strong evidence-based research supporting their use.

Driving Assessment Tools

There are many different tools used in driving evaluations, and one alone is not sufficient alone as a valid predictor of fitness-to-drive (Classen et al., 2012; Fields & Unsworth, 2017).

Because of this, a behind-the-wheel (BTW) assessment is often argued to be the gold standard in a driving evaluation. Unfortunately, there is limited consistency in the way BTW assessment are conducted and end results determined (Dickerson et al., 2012). Furthermore, there is not consistency in the other clinical assessment tools used by occupational therapy driver rehabilitation specialists (OT-DRSs) (Dickerson, 2013).

Dickerson (2013) found the three most common clinical assessment tools that DRSs use are tests of visual acuity, range of motion of the upper extremity, and range of motion of the head, neck, and trunk. When dealing with a client that likely has cognitive deficits the Clock Drawing Test (Dal Pan et al., 1989), Letter-number cancellation (Ruff et al., 1986), and Motor-free Visual Perception Test (MVPT) (Colarusso & Hammill, 1972) were the three most common assessments (Dickerson, 2013). The three assessments most considered when deciding about fitness-to-drive are BTW, vision testing, and Trails A and B (Reitan, 1958) or Trails B (Dickerson, 2013). In their review, Fields and Unsworth (2017) found Trails B to be the most recommended cognitive and perceptual assessment tool, followed by Trails A, and Useful Field of View (UFOV™).

The Trail Making Tests, Part A and B were designed to assess attention, with Trails A focusing on simple, sustained attention and Trails B focusing on complex, divided attention (Holowaychuk et al., 2020). Both are frequently used in driving evaluations, however there are variable findings as to which trails test has the best utility in driving evaluations. Holowaychuk et al. (2020) found there to be significant evidence for the use of both Trails A and Trails B. The same paper does acknowledge that Trails B completion time alone was significantly predictive of the pass/fail result of an on-road driving evaluation. Classen, Wang, Crizzle et al. (2013) also showed a connection between Trails B performance and pass/fail outcomes on an on-road test.

Conversely, Barco et al. (2014) found that Trails A was part of the best model to predict pass/fail results for an on-road test. Some question the use of Trails A or Trails B, finding that together they have a predictive value of only 9.5% (Vaucher et al., 2014).

The UFOV™ is a test which can be used to measure divided attention, a form of multitasking, like Trails B (Classen, Wang, Crizzle, et al., 2013). Because driving is an IADL which requires splitting attention between many different challenges, the UFOV™ may be a valid predictor of driving performance, especially in older adults and in people with neurological disorders. The UFOV™'s sensitivity (.88 for UFOV™ 2 and .81 for UFOV RI at cutpoint 2) and specificity (.63 for UFOV™ 2 and .81 for UFOV RI at cutpoint 2) was shown to be a more predictive measure of on-road success compared to other tests such as Trails B (Classen, Wang, Crizzle, et al., 2013). There is, however, research that questions just how predictive of driving performance UFOV may be. Bédard et al. (2008) found that it could not safely predict safe or unsafe driving with enough accuracy to make any decisions based on the outcome. They explain that at a cutoff where 80% of unsafe drivers are identified 44% of those identified as "unsafe" would be safe to drive. Using a less strict cutoff point to minimize the number of individuals who are safe to drive being classified as unsafe would lead to fewer drivers who are unsafe being classified as such (Bédard et al., 2008). This indicates that UFOV™ may not have the balance of sensitivity and specificity to be an accurate enough predictor of driving safety, even if it does outperform some other measures.

The Motor-Free Visual-Perceptual Test (MVPT) assesses an individual's spatial relationships, visual closure, visual discrimination, visual memory, and figure ground without the individual having to use a motoric response (Oswanski et al., 2007). Oswanski et al. (2007) found that the MVPT was significantly predictive of older drivers' ability to perform an on-road test. Holowaychuk et al. (2020), however, found that MVPT was less predictive of on-road driving performance than alternatives like Trails B.

A variety of more general cognitive assessments are also frequently used, one of these being the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). The MoCA is scored on a 30-point scale and measures cognitive abilities like memory, language, visuospatial processing, attention, and even abstract thought (Burns et al., 2018). The MoCA has been linked to fitness to drive with Esser et al. (2016) finding that a MoCA score in the range of 12 to 26 yielded a 50% chance of failing an on-road test. Others have found that there are cognitive assessments like the Cognitive Performance Test (CPT) which have greater sensitivity and specificity when predicting whether an individual will pass or fail an on-road test (Burns et al., 2018).

In addition to these more common options, there other assessments used by occupational therapist driving rehabilitation specialists, although few have sufficient literature to support their use in driving assessments. Some have begun using new technologies like interactive driving simulators, but as of 2013 just over 10% of DRSs use any form of driving simulator in their clinical assessment (Dickerson, 2013).

Driving Simulators

Taking potential drivers out in motor vehicles on public roads can be expensive, time consuming and limited in areas where there are no OT-DRS located (Dickerson et al., 2012). This is one reason that driving simulators are now beginning to be used in driving research and evaluations. Another benefit is that there are many different driving simulators and simulator tasks made for different purposes (Classen & Evans, 2017). Differences in simulators can be in the physical simulator itself or in the software it runs and therefore the tasks it can have people complete. Some simulators will have full or partial car cabs. This gives a more realistic estimation of the experience of being in a car. Other simulators will simply have the steering wheel, pedals, and screen. These are more convenient, require less space, but are less of a close approximation of the experience of being in a car (Classen & Evans, 2017).

Clinical Driving simulators are the most commonly used type of driving simulator by healthcare professionals in client evaluation and treatment (Classen & Evans, 2017). These are designed to be significantly more convenient, cheaper, and easier to use. Additionally, these kinds of simulators have different scenarios programed into them. These programs can range from nondriving exercises using the simulator interface to simple driving activities to advanced driving evaluation tasks (Classen & Evans, 2017). The designed software and task being presented to the participant or client are perhaps more important than the realism of the simulator itself in a clinical context or certain research contexts where specific skills (e.g., peripheral vision) are being observed more than overall driving skill (Classen & Evans, 2017).

Simulators have the potential to be powerful tools within both occupational therapy evaluation and intervention. First, with evaluation, simulators possess significant advantages to on-road driving in both a clinical and research setting. One advantage is that they are fully standardizable and consistent. On-road tests can be unpredictable, but with programming a simulator can be perfectly controlled (Classen & Evans, 2017). Another advantage of driving simulation is the objective data output at the end of the task. This data can be used for research purposes to compare people between different variables or in clinical settings the data can be used for cutoff points (Classen & Evans, 2017). Different programs can give more than one output for more than one simultaneous task (Classen & Evans, 2017). This means that those objective scores can be combined to measure overall performance, effectively as a measure for multitasking ability since while driving in a simulator the tasks can be programmed to be presented simultaneously or in a predetermined sequence.

Interactive driving simulators can give a very accurate representation of on-road performance for certain skills, further contributing to their usefulness in driving evaluations. One such skill is wayfinding. Cochran and Dickerson (2019) found that performance on a wayfinding task using a paper map, or a GPS was nearly identical whether the participant was performing the task on the road or on the interactive driving simulator (Cochran & Dickerson, 2019). Another skill with great similarities between simulation and on-road driving is hazard detection. Leonardo and Dickerson (2020) used eye tracking to show that in nighttime conditions target detection performance, as measured by eye tracking software, was very similar between the simulated scenario and the on-road scenario (Leonardo & Dickerson, 2020). Research has also shown that between an on-road drive and a simulated version of the same drive individuals held statistically similar speeds through most of the drive (Bella, 2007).

Interactive driving simulators have also demonstrated strong validity in their ability to predict on-road performance. In a three-year longitudinal study with 129 participants Lee and Lee (2005) developed ten different levels on a driving simulator, with each focused on a different discrete skill. At the end of the three years, they found that performance on the working memory level and use of indicator level was correlated with rate of traffic violations and had potential to identify potential unsafe drivers (Lee & Lee, 2005).

Bédard et al. (2010) also validated a driving simulator by correlating performance on the simulator with not only Trails A and Trails B, but also an on-road test. Furthermore, this study showed that with a well-defined protocol for grading a simulated drive there was consistency between, and within graders (Bédard et al., 2010). This is important to make driving simulation tools generalizable, and to track clients' progress over time accurately.

Importantly, participants seem to generally see driving simulators, even ones with only one or three screens, as an acceptable tool for driving assessment. Despite some concerns with the realism of driving simulators, most feel that they offer a fair and reasonable picture of their true driving ability (Gibbons et al., 2014).

Driving Simulators can Gauge Multitasking/Processing Speed

Driving simulators have the potential to carefully target the discrete skills they seek to identify and to yield data that strongly correlate with on-the-road results. Blane and colleagues (2017) compared simulation performance between licensed stroke patients and healthy individuals and found no significant differences in simulator performance except for an indication that those with stroke did not vary their headway as much. These results were expected because all the participants were experienced, and therefore should be competent drivers (Blane et al., 2017). These results compared simulator results to expected on-road performance, validating the simulator as a tool to help understand fitness-to-drive.

In a different way, Hoe and colleagues used driving simulation to demonstrate visual attention skill of older drivers declines with age. Because this result was congruent with available literature, they concluded that the driving simulator could be a tool that works for screening older adult drivers (Hoe, 2003). These results compared simulator results to a specific skill, validating the simulator as a tool to help understand and measure that specific skill rather than as an examination of fitness-to-drive.

Classen, Monahan, and Wang (2013) found that when comparing simulator summary data of individuals with attention deficit hyperactivity disorder and individuals with autism spectrum disorder there were no differences detected in simulated elements of driver safety, like collision avoidance, despite differences detected in other testing. They assert that this means driving simulators alone might not be sensitive enough to detect performance differences in driving between the two populations (Classen, Monahan, & Wang, 2013). This raises concerns about the effectiveness of driving simulation to be sensitive enough to directly indicate on-road safety and performance, but they still have a distinct value in the driving evaluation process. In fact, despite the simulator not identifying a difference, a trained OT-DRS was able to identify differences in performance not reflected in the simulator output, reinforcing the importance of having a skilled professional present and observing (Classen, Monahan, & Wang, 2013). Interactive driving simulators can be programmed with scenarios that let the occupational therapist target very specific skills (Classen & Evans, 2017). Throughout the trial the practitioner or researcher can get observational data, but the simulator can also provide objective data summary (Classen & Evans, 2017). With this information, the driving evaluator gains an important extra piece of data to use in the process of the comprehensive driving evaluation.

Summary

Processing speed and multitasking ability naturally decline over time and can be greatly affected by a variety of neurological conditions. A decline or loss in these abilities can decrease an individual’s ability to drive, especially when carrying out quick decisions necessary in the tactical level of driving as described by Michon (1985). A driving evaluation performed by an occupational therapist/driver rehabilitation specialist may be necessary to determine an individual’s fitness to drive at this point. Traditionally, when doing a driving evaluation on a client with cognitive deficits the evaluator would use assessments like the Clock Drawing Test, Letter-number cancellation, and the MVPT. These assessments can help the evaluator to see the individual's attention, memory, visual perception, and more, but they do not simulate driving, nor do they strongly involve significant processing speed or multitasking. Interactive driving simulators are a tool that can be used in driving evaluation and have the potential to give insight into processing speed and multitasking ability. This may help the evaluator get a clearer picture of the individual's abilities and determine their fitness to drive.

Thus, the purpose of this study is to use a driving simulator to assess multitasking abilities of people from different age groups for the purposes of clinical norms and to compare results between age groups. Much of previous multitasking research involving driving or driving simulation has involved a task being introduced that is not driving related, but driving is itself a complicated and multilayered IADL. This study will assess whether a driving simulator-based measure of multitasking ability produces results consistent with age differences and/or medical conditions found in other multitasking studies and clinical accounts. Essentially, we are establishing norms for an assessment of multi-tasking on the DriveSafety™ Interactive Driving Simulator's *Functional Object Detection – Advanced* program as a fitness-to-drive outcome measure.

Specifically, the research questions:

1. Is the performance of individuals on a driving-simulator assessment of multitasking correlated with their fitness-to-drive?
2. Does the performance of individuals on a driving-simulator assessment of multitasking differ between medically at-risk and healthy controls?

Methods

Design

A cross-sectional quasi-experimental design was used with a group of healthy, community living adults based on age group, and a group of medically at-risk individuals. Medical status (healthy, medically at-risk) was an independent variable. The main dependent variable was participants' performance on the simulator, measured both by last level completed and whether a level was ever failed. Another dependent variable was the fitness to drive classification. A quasi-experimental design was appropriate for this study because the independent variable, medical status, is not manipulated and there was no randomization.

Participants

Healthy adults: Healthy adults were recruited from the community. These individuals self-reported they were in good health via a survey and indicated that they had valid driver's licenses. Inclusion criteria for the healthy adult groups was scoring 23 or higher on the MoCA to verify that cognitive issues are not a confounding variable for the healthy groups. Exclusion criteria for the healthy adult groups included having a current health condition that may affect driving ability in addition or below the age of 18. Healthy participants were classified as part of a group aged 18-30 (young), another aged 31-64 (middle), or another aged 65 and up (older). Data had already been collected on healthy older adults (N=41). In total, there were 131 healthy adults in this study, 60% of which were female, 40% male, and with a mean age of 47.9 years.

Medically at-risk adults: The medically at-risk adults were identified through ECU Health Medical Center (formerly Vidant Medical Center) who were completing a driving evaluation with an occupational therapist and agreed to allow their data to be used in the study (UMCIRB 18-002080). These individuals were included if they were adults that had a medical diagnosis which may have impacted their driving ability and needed a comprehensive driving evaluation to determine their fitness to drive. In addition to the data already collected from a previous study (Penna), 53 more were collected for a total of 124 participants in this group, 30% were female, 70% were male, and the average age was 61.7.

This study was approved by the East Carolina University UMCIRB (UMCIRB 20-002156). Written consent for all healthy and medically at-risk participants was obtained.

Equipment

The DS 200 DriveSafety™ is an interactive driving simulator that can be used to measure physical function, cognitive function, and vision of participants or clients (DriveSafety™). While not having the full simulation physical car interior, it has the same software capabilities for testing and measuring driving skills as other DriveSafety™ simulators (DriveSafety™).

The simulator is comprised of a steering wheel mounted on a desk, pedals mounted under the desk, and three computer monitors on the desk. Users sit at a standard chair to use the simulator, and the desk is adjustable for those with different lengths of legs. See Appendix C for a photo of the simulator.

Instrumentation

The *Montreal Cognitive Assessment* (MoCA) (Nasreddine et al., 2005) was used for as a screen for cognitive impairment. The MoCA has 30 questions that aim to measure a variety of cognitive functions (Nasreddine et al., 2005). At a cutoff score of 26 demonstrated 90% detection for Mild Cognitive Impairment and 100% detection for Alzheimer's Disease. It also had good specificity at 87% (Nasreddine et al., 2005). While the cutoff score for the MoCA has been 26 in the literature, based on primarily data and other research (Malek-Ahmadi et al., 2015), 26 may be too strict of a cutoff for some studies, especially with older adults and levels of education.

DriveSafety™'s *Functional Object Detection (FOD) – Advanced* was used to provide outcome measures as proxies for multitasking and processing speed. This program allows the user to change the number of tasks the participant is responsible for and change the difficulty of individual tasks. These three main tasks used in this study included: 1) pressing the brakes when the vehicle, in front of the "driver", brake lights illuminate, 2) pressing the right or left red button on the steering wheel when an 'E' appears on the corresponding left or right side of the vehicle on the screen, and 3) maintaining the vehicle within the correct lane of the roadway.

The FOD tasks on the DriveSafety™ simulator are based on and build on another simulator developed by Goodenough et al. (2012) which looked at only brake light response and visual stimulus response which was the equivalent of the E in the DriveSafety™ FOD (Brooks et al., 2017). The study indicated that the similar simulator was able to show differences in ability to scan the environment while simultaneously focusing on the braking task (Goodenough et al., 2012).

Since there are numerous ways to structure the different task difficulties, a pilot study was completed before determining the final characteristics for this study. The pilot study used an occupational therapist expert in activity analysis and grading the tasks to identify levels of complexity, specifically adding more tasks to create an increasingly complex task that requires multi-tasking. The eight levels were used with community living older adults (N=69). Based on an ANOVA analysis of scores at each of the eight levels it was clear that several levels, although they had an increased task, were not significantly different from each other. Thus, two levels were eliminated, and tasks modified to have levels that demonstrated a hierarchy of multitasking. Table 1 shows the p-values found from t-tests comparing performance between levels 3, 4, and 5. Table 2 shows the p-values found from t-tests comparing performance between levels 6, 7, and 8. They clearly show the lack of a significant difference between levels 4 and 5 and levels 7 and 8. Thus, level 4 and level 7 were the levels removed.

Table 1

Pilot Comparison Between Levels 3, 4, and 5

Comparison Between	p-value
Level 3 and Level 4	<0.0001
Level 4 and Level 5	0.7833

Table 2

Pilot Comparison Between Levels 6, 7, and 8

Comparison Between	p-value
Level 6 and Level 7	0.0188
Level 7 and Level 8	0.8010

Following the pilot study finding that some levels were not statistically different from levels “above” or “below,” the final determination for the grading of difficulty was six “levels” with the first level being equal to a practice. The final levels and tasks involved in each one are outlined in table 3.

Table 3

Final Six Level Protocol

Level	Tasks
1	1. Brake when the lead vehicle’s brake lights are activated (Brake Task) 2. When the letter ‘E’ appears for two seconds, press the right or left red

	button on the steering wheel corresponding to where the E appears on the right or left side of the lead vehicle (E-Task) 3. Stay centered in the appropriate right lane (Lane Maintenance)
2	1. Maintain target speed of 35 2. Brake Task 3. E-Task 4. Lane Maintenance
3	1. Maintain target speed of 35 2. Brake Task 3. E-Task 4. Lane Maintenance 5. Avoid pressing any backward facing 'E' (Distractor Task)
4	1. Maintain target speed of 45 2. Brake Task 3. E-Task with a third row of 'E's to increase time the level took (Durability) 4. Lane Maintenance 5. Distractor Task
5	1. Maintain target speed of 45 2. Brake Task 3. E-Task without third row 4. Lane Maintenance 5. Call out numbers when they appear in rearview mirror
6	1. Maintain target speed of 45 2. Brake Task 3. E-Task without third row 4. Lane Maintenance 5. Distractor Task 6. Call out numbers when they appear in rearview mirror and side mirrors

Level 1 required the participant to complete the main three tasks only, without needing to use the accelerator (cruise control on). There are three central tasks which remain the same at each level; these require the individual to 1) brake when the lead vehicle's brake lights are activated, 2) when the letter 'E' appears for two seconds, press the right or left red button on the steering wheel corresponding to where the E appears on the right or left side of the lead vehicle, and 3) stay centered in the appropriate right lane. Level 2's tasks were identical, but the participant controlled the speed of the car as well with a target speed of 35 mph. Level 3 added a distractor, which were backward-facing E's which the driver was to ignore. Level 4 added a third row of 'E's (sustainability), and target speed of 45 mph and three types of distractors. Level 5 removed distractors and added a number that appeared in the rearview mirror randomly that the participant needed to read aloud (which appeared when the driver used the brake sufficiently hard enough to trigger). Level 6 had numbers appearing in the rearview and side mirrors, requiring the participant scan the entire screen area to identify and call the numbers, and it again contained distractors. Each level added more cognitive load required for the driver, contributing to strong face-validity of this instrument.

For the first two levels, the participants were given up to three opportunities to meet the 80% criteria for the brake and E target tasks. For the rest of the levels, if a participant failed a single task by getting less than 80 percent in the braking or target recognition, then the procedure could be stopped to avoid frustration, if it was clear the tasks were too complex for the participant.

Procedure

For recruitment of healthy participants, study information was posted online to social media pages, looking for volunteers, and clearly advertising the inclusion and exclusion criteria. Additionally, eligible former-participants of other studies were contacted. Participants contacted us to schedule an appointment. Once a participant arrived, they were assigned a participant ID number, they read the consent form and signed it. Participants were administered the MoCA and were asked to rate their overall health on a scale of 1 to 5 (1=very poor, 2=poor, 3=fair, 4=good, and 5=excellent). Upon completion, the DriveSafety™ FOD simulator tasks were initiated. The directions found in Appendix B were followed.

All the printed sheets with the number of the level it contains data for and if it was the participant's first, second, or third attempt were labeled, stapled together, and entered into the data files. For tasks 5 and 6 the number of numbers in the mirrors that the participant got incorrect were recorded on the corresponding printed sheet.

Once the participant discontinued the tasks, or successfully completed them all, they were thanked for their participation, their gift card was given to them, and they were asked to refer people they know to the study. The printouts of all the levels were with only the participant's ID number was collected and transferred to an electronic file for analysis. All the data from the printouts was recorded into a well-organized excel spreadsheet.

Data Analysis

First, driving outcomes were compared between the healthy and medically at-risk groups using a chi-square analysis. Average age of those who were considered fit and not fit to drive was determined, and independent t-tests were used to evaluate differences in average age for each category. Then, the raw data were analyzed to determine what participants had failed at a level and which had not. With this information, driving outcomes were compared between those who had never failed a level and those that had failed one of the six levels using a chi-square analysis.

Following these analyses, survival curves were created for the six levels. One survival curve included two strata – healthy and medically at-risk. The other survival curve included two different strata – fit to drive and not fit to drive. Then, three ROC models were created, each including a different set of variables analyzed with chi-square analyses. Finally, the three models were compared to each other with chi-square analyses.

Results

Participant Demographics

Table one shows the group of 131 healthy, community-living participants had an age range from 21 to 87 and a mean of 47.9 (SD=21.9) years. The group was 60% female and 40% male. The group of 124 medically at-risk participants had an age range from 16 to 90 and a mean of 61.7 (SD=15.5). This group was 30% female and 70% male.

Table 3

Demographics Between Groups

	Healthy Adults (N=131)	**Medically at-risk Adults (N=124)**
Age Range	21-87	**16-90**
Mean Age	47.9	**61.7**
% Female	60%	**30%**
% Male	**40%**	**70%**

Differences in "Driving Outcomes"

Table 4 shows the driving outcomes of all participants from the study. As expected, especially with over half of the participants being healthy adults, significantly more participants were considered fit to drive. Of the 255 total participants, 76 (29.8%) were considered not fit to drive while 179 (70.2%) were considered fit to drive. Table 5 compares the driving outcomes of the two groups. Only 4 participants of the 76 considered not fit to drive (5.26%) were healthy controls, while the rest were medically at-risk participants. Furthermore, 52 of the 179 participants considered fit to drive (29.05%) were in the medically at-risk group. The chi-square analysis for Table 5 yielded a p-value of <.0001, indicating there is a statistically significant difference between the driving outcomes of healthy controls versus medically at-risk participants.

Table 4

Overall Driving Outcomes

	Fit To Drive	Not Fit to Drive
Total	179	76
% of Participants	70.2%	29.8%

Table 5

Driving Outcomes Between Groups

	Fit to Drive	Not Fit to Drive	Totals
Healthy Control	*127(70.95%)*	*4 (5.26%)*	*131*
Medically at-risk	*52 (29.05%)*	*72 (94.74%)*	*124*
Totals	*179*	*76*	*255*

The data also revealed a connection between driving outcome and age. Table 6 shows the mean age and standard deviation of those that were considered fit and not fit to drive. Those considered not fit to drive had an average age of 69.7 years while those considered fit to drive had an average age of 48.3. Both pooled and Satterthwaite T-tests yielded a p-value of <.0001. This means that there is a statistically significant difference between the ages of those considered fit and not fit to drive.

Table 6

Age and Driving Outcome

	Average Age	Standard Deviation
Fit to Drive	48.3	**20.04**
Not Fit to Drive	**69.7**	**10.38**

Figure 1

Distribution of Age Versus Driving Outcome

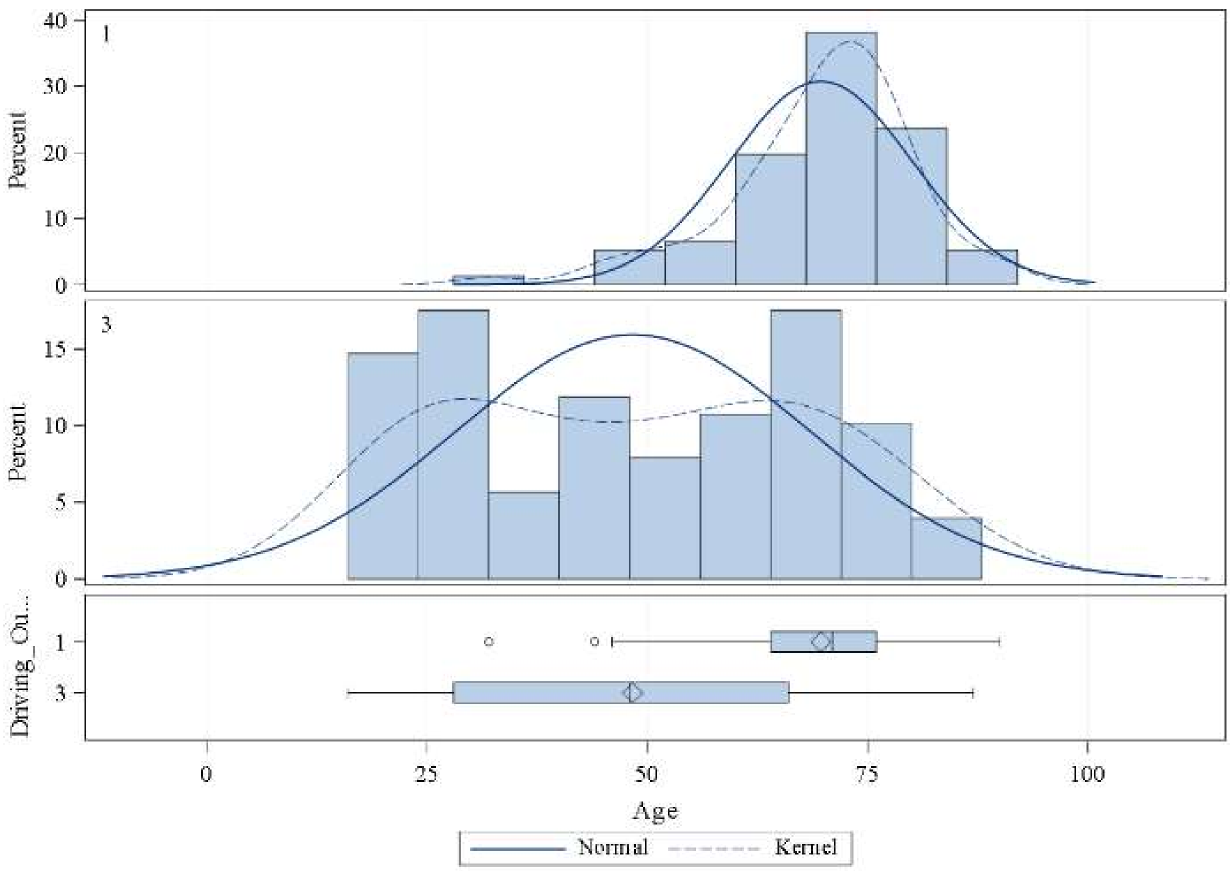


Figure 1 graphically illustrates the difference in age distribution between the two driving outcomes. The top graph shows the age distribution of those considered not fit to drive while the second graph shows age distribution of those considered fit to drive. The box plot shows the same respective distributions in a different format, more clearly demonstrating the difference in means.

Differences in Simulator Performance

Table 7 shows the distribution of participants that never failed at a level versus failed at any level based on whether they were considered fit or not fit to drive. 192 participants never failed at a simulator level, while 63 participants did fail one of the six levels. Of those considered fit to drive, 165 (92.18%) participants never failed a simulator level and only 14 (7.82%) did fail a level. Conversely, of those considered not fit to drive only 27 (35.53%) participants did not fail a level while 49 (64.47%) did fail one of the six levels. The chi-square analysis for this chart resulted in a p-value of <.0001, indicating that there is a statistically significant difference in simulator performance between those considered fit to drive and those considered not fit to drive.

Table 7

Simulator Performance Between Fit and Not Fit to Drive Participants

	Fit to Drive	**Not Fit to Drive**	**Totals**
Never Failed Level	*165 (92.18%)*	*27 (35.53%)*	*192*
Failed Any Level	*14 (7.82%)*	*49 (64.47%)*	*63*
Totals	*179*	*76*	*255*

To further emphasize this point, a survival curve was created comparing fit and not fit to drive individuals on their "survival" through the six levels. The mean level completed for the not fit to drive individuals was 3.6, while the mean level completed for the fit to drive individuals was 5.9. A test of equality over strata yielded a chi-square with a p-value of <.0001, further reinforcing statistically significant differences in simulator performance between the fit and not fit to drive groups. These analyses appear to answer the first research question, suggesting with multiple statistical methods that simulator performance has a statistically significant connection to fitness to drive. Figure 2 shows the survival analysis curves with fit to drive individuals represented in red and not fit to drive individuals represented in blue.

Figure 2

Simulator Level Reached Versus Fitness to Drive

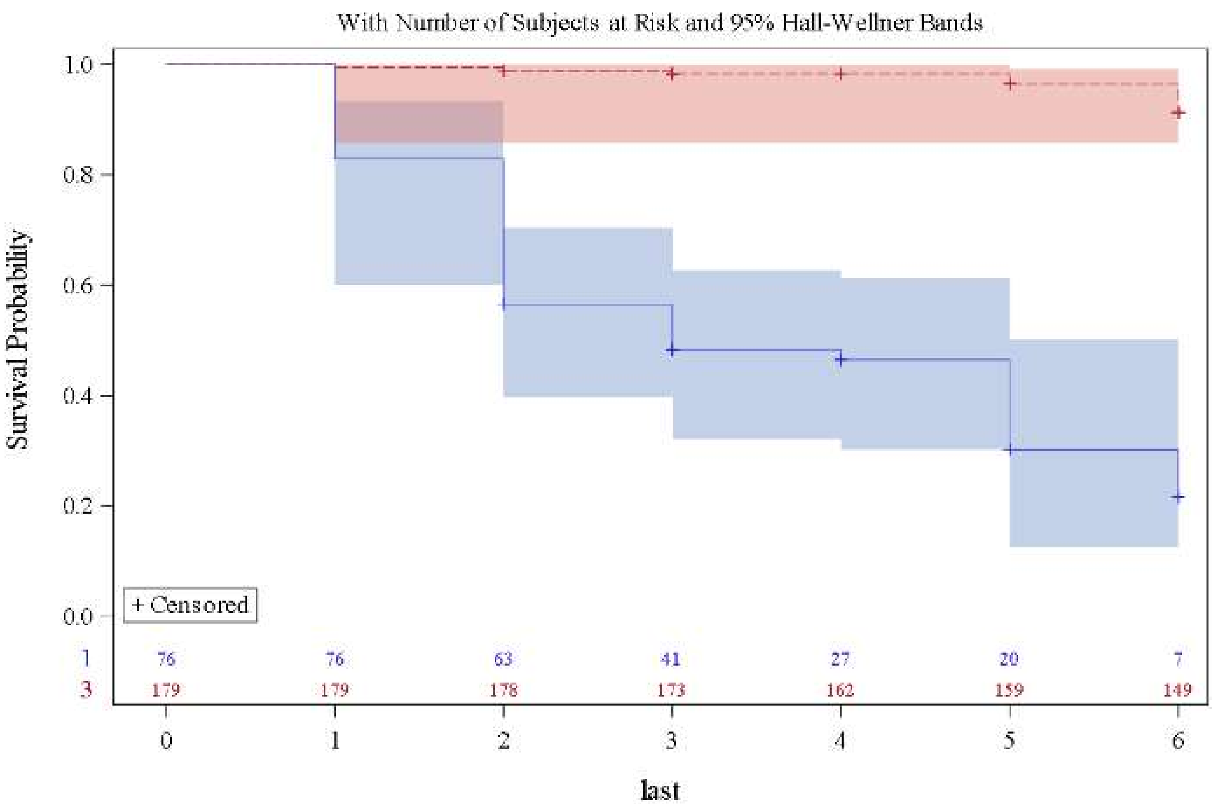
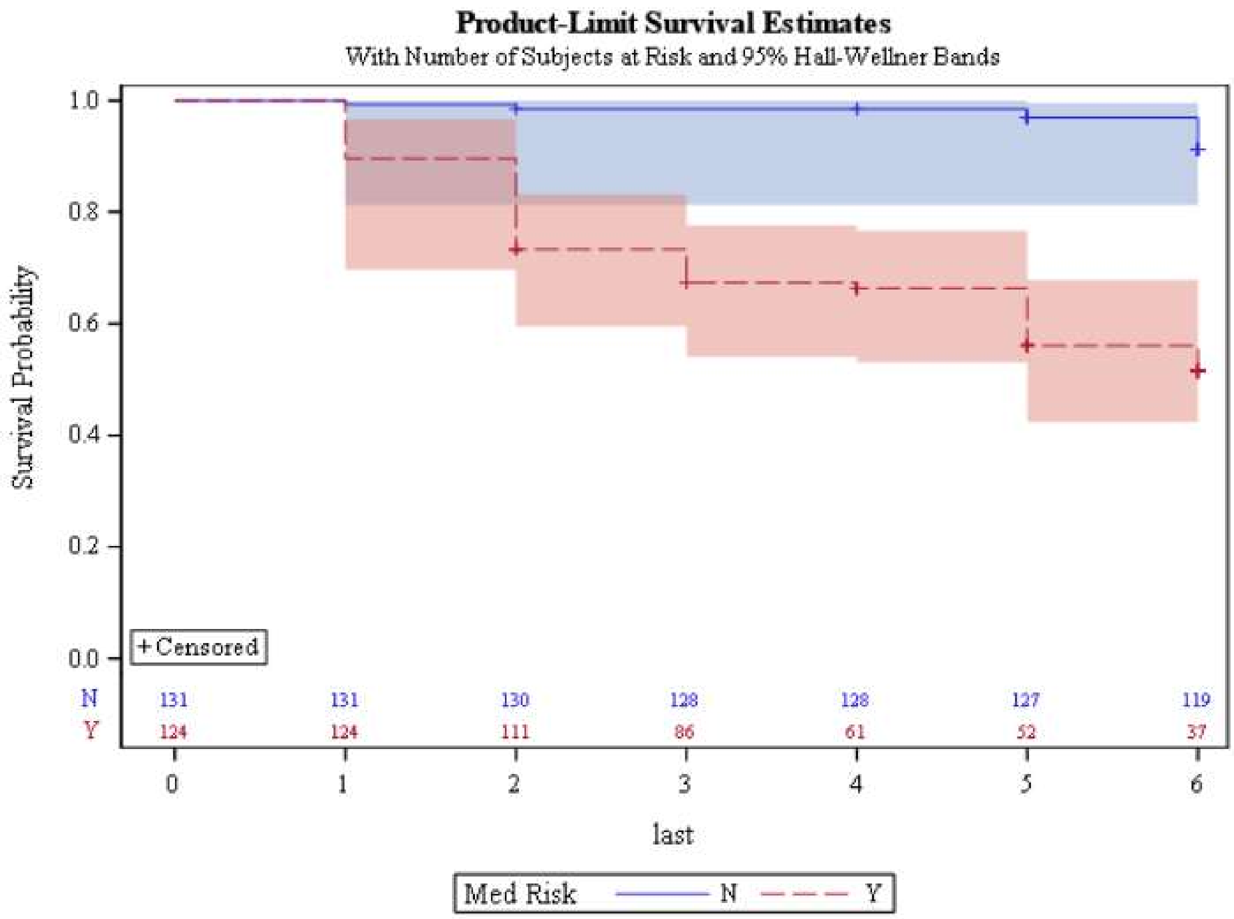


Figure 3 shows the survival analysis curves with medically at-risk individuals represented in red and healthy controls represented in blue. Similarly to the comparison between fit to drive and unfit to drive individuals, there is a clear and significant difference between the two groups in their simulator performance. The mean level reached by healthy controls was 5.9 while the mean level reached by the medically at-risk group was 4.5. A test of equality over strata yielded a chi-square with a p-value of <0.0001. This means that, answering the second research question, there was a statistically significant difference in simulator performance between the medically at-risk group and healthy control group.

Figure 3

Simulator Level Reached Versus Medical Status



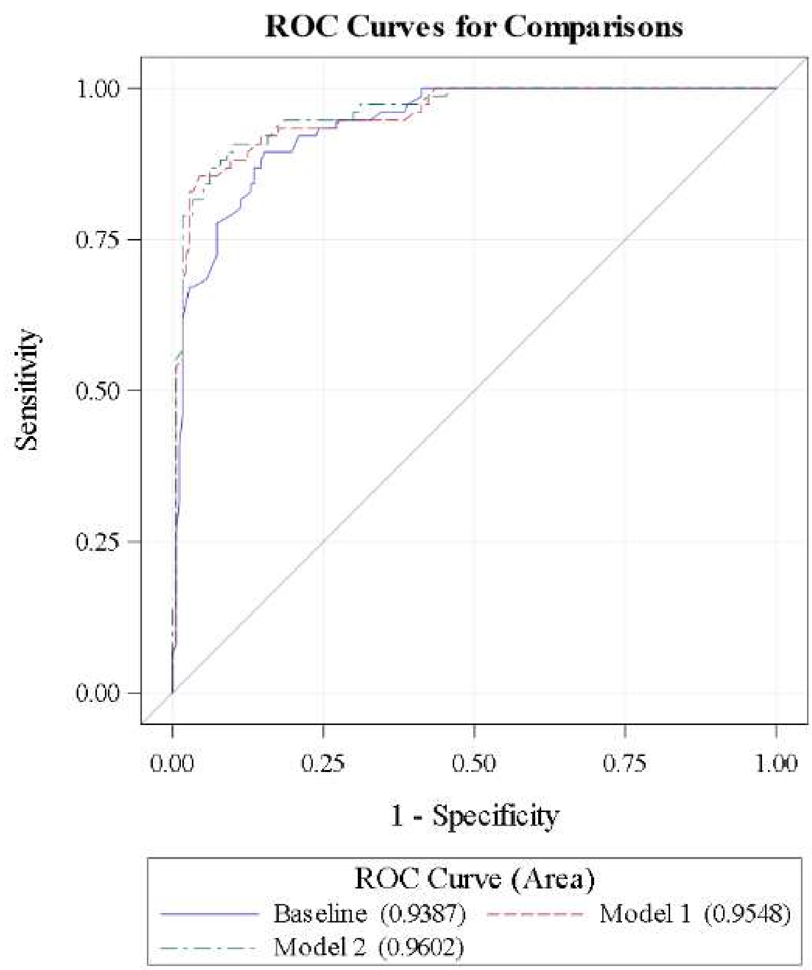
Models for Predicting Driving Outcomes

Three ROC models for explaining driving outcomes were created using the data. Each model had its own set of variables included. The baseline model used only age and medical risk as predictive variables. Model 1 used age, medical risk, and whether a participant ever failed a simulator level as predictive variables. Model 2 used age, medical risk, whether a participant ever failed a simulator level, and last simulator level completed as its variables. Notably, when testing the null hypothesis for each model with a chi-square analysis, p-values of <.0001 were yielded for all three. Therefore, each model has statistically significant predictive ability.

Figure 4 is a graphical representation of ROC curves for all three models. It shows that the areas under the curve (AUC) of the baseline model, model 1, and model 2 are 0.9387, 0.9548, and 0.9602 respectively where numbers closer to 1 indicate a model with higher sensitivity and specificity. AUC values between. 0.9 and 1.0 are considered widely considered to be excellent (Safari et al., 2016).

Figure 4

ROC Curves for Three Models



Statistical Comparison Between Models

Table 8 shows the results of chi-square analyses between each of the three models. The analysis comparing the baseline model to model 1 yields a p-value of 0.0292, suggesting that model 1 is a better, more predictive model because it adds the factor of whether an individual fails a simulator level. Comparing the baseline model to model 2 yields similar results – a p-value of 0.0107 indicates that model 2, with its consideration for failing a simulator level and the last level completed, is a statistically superior model compared to the baseline. The chi-square analysis comparing models 1 and 2 yields different results. The p-value of this analysis is 0.1968, which is greater than the alpha level of 0.05. This means there is not a statistically significant difference between models 1 and 2 – the addition of last level completed to the model does not appear to be a statistically significant addition according to this analysis.

Table 8

Comparison of Three Models

Comparison	**Chi-Square**	**Pr>ChiSq**
Baseline vs. Model 1	*4.7538*	*0.0292*
Baseline vs. Model 2	*6.5210*	*0.0107*
Model 1 vs. Model 2	*1.6658*	*0.1968*

Discussion

The purpose of this study was to explore differences in performance in the ability to multi-task between individuals who were considered either fit to drive or unfit to drive using an interactive driving simulator. The DriveSafety™ simulator and FOD Advanced levels were used to design the various levels of multi-tasking in a hierarchical format to determine if this specific driving simulator could function as an assessment tool for fitness-to-drive. The results of this study were overall consistent with the initial hypotheses. Unsurprisingly, the mean age of participants in the healthy control group was significantly lower than the mean age of the medically at-risk group, likely due to risk of developing medical conditions increasing with age (Smajlović, 2015). Comparing simulator performance between the healthy control group and the medically at-risk group yielded statistically significant results which support previous literature about medical conditions affecting an individual's cognitive abilities, including multitasking (Gale et al., 2018; Khellaf et al., 2019; Knight-Greenfield et al., 2019; Lo Coco et al., 2016; Lord et al., 2018; Murman, 2015; Rao, 2012). The fact that these results were consistent with the existing literature supports the use of this task as a tool to differentiate those with and without medical conditions based on this multi-tasking ability tested on this six level, increasingly complex task.

While having data to support the idea that a discrete cognitive skill can be measured with the driving simulator was an important step in this project, it still did not immediately indicate that it would be a useful tool for determining fitness-to-drive. This was because within both groups (i.e., healthy controls, medically at-risk), there were those who ultimately were considered fit-to-drive and others who were considered unfit-to-drive. Simulator performance was compared between fit and unfit-to-drive individuals instead of between healthy controls and medically at-risk adults to have a more true and fair representation of how the simulator performance related to fitness-to-drive results. The results were computed in multiple tests and formats, all rendering the same general conclusions. Firstly, and unsurprisingly, passing every level on the simulator appeared to be correlated with being fit-to-drive, while failing a level on the simulator appeared to be correlated with being unfit-to-drive. As a test of multitasking ability, it makes sense that driving simulator success was correlated with fitness-to-drive due to driving's high demand for multitasking. Secondly, it was found through multiple statistical analyses that ***which level a person failed was not a statistically significant indicator***. Surprisingly, this means failing at level one versus level three versus at level five did not appear to indicate a statistically significant increase in propensity to be classified as unfit-to-drive. Regardless of the level of failure, if a person did not achieve at least 80% on the top main tasks (i.e., braking, identifying the Es on the correct side), they were very likely to fail the on-road assessment. There may have been a significant relationship between the specific level an individual failed and their fitness to drive, however, if individuals' scores for the on-road portion were analyzed rather than the binary pass/fail decision.

Very few individuals who were considered fit-to-drive ever failed a simulator level, compared to most individuals who were considered not-fit-to-drive who did fail a simulator level. This means that generalist practitioners can use this tool with some confidence but should still consider other factors as simulator performance was not a perfect indicator. Not only is using whether a person ever failed a level as the warning sign easier, it was also shown to be statistically similar to comparing the last level an individual successfully completed. Altogether, this means that failing a simulator level at any point can be considered the "red-flag" according to the data and analyses completed for this study.

Receiver operating characteristics (ROC) curves are useful for evaluating models with binary outcomes, plotting the sensitivity and specificity of the model at various cutoff points (Safari et al., 2016). In the case of this study, they applied and were useful because the outcome of fit to drive versus unfit to drive is a binary one. The baseline model, which only considered age and medical status, was, perhaps unsurprisingly, an incredibly strong model on its own. This is in support of the extensive literature outlining both that age and medical conditions significantly impact fitness to drive. The assessment tool, or simulator protocol used in this study, made the model even stronger. This means that, even though a generalist OT may assume something about an individual's fitness to drive given their age and medical status, it is better to use the simulator protocol in addition to those details when making a final recommendation. Ultimately, the results of this study show that using the simulator can help a generalist OT to more confidently and correctly determine whether it is appropriate for an individual to see and OT-DRS for a comprehensive driving evaluation.

Application to Occupational Therapy Practice

Driving and community mobility is under the scope of any practicing Occupational Therapist as an instrumental activity of daily living (AOTA, 2020). Generalist practitioners will likely only be screening for the need to refer clients to further evaluation in the form of a comprehensive driving evaluation (Dickerson et al., 2011). The data from this study do not suggest that the interactive driving simulator was 100% effective in identifying fit versus unfit-to-drive individuals, however the data do suggest that this interactive driving simulator assessment had a strong correlation to fitness-to-drive.

More specifically, failing a level at any point appears to be a "red-flag," strongly related to being unfit-to-drive. The advantage of this assessment is the face validity of the driving task.

Individuals being tested may understand the relationship of braking and scanning the screens for targets over Trials B of connecting dots or making a clock. This makes this assessment tool easy to structure and use as an indicator for potential fitness to drive. If a generalist occupational therapist is using this tool and a client fails any level of the six used in this study, the data suggest that the individual will likely fail a driving evaluation at that time. This would make it an easy decision for the generalist to refer their client to an OT-DRS so that the client can be more fully assessed through a comprehensive driving evaluation. By using this tool combined with a comprehensive occupational profile and other functional assessments, specifically looking at instrumental activities of daily living (IADLs) function, a generalist OT should be able to provide a confident and appropriate recommendation to their clients.

Furthermore, this tool is also useful to generalists because, anecdotally and observationally, participants in the study expressed their thoughts and feelings that the simulator was fair and clearly related to driving. Other assessments frequently used in driving evaluations include Trails A and Trails B (Reitan, 1958), Motor-free Visual Perception Test (MVPT) (Colarusso & Hammill, 1972), and the Clock Drawing Test (Dal Pan et al., 1989) (Dickerson, 2013). While these assessments do measure important discrete skills, they do not bear any clear resemblance or relationship to driving. Both medically at-risk and healthy controls often expressed that while the simulator did not perfectly recreate an on-road feeling, the tasks felt clearly related to driving skills. The participants' sentiments were consistent with available literature regarding use of interactive driving simulators (Gibbons et al., 2014).

An interactive driving simulator protocol such as the one examined in this study offers an opportunity to increase consistency in assessments used to determine fitness to drive. It has been shown that there is significant inconsistency in what assessments are used to determine fitness to drive, and one assessment alone is insufficient (Classen et al., 2012; Dickerson, 2013; Fields & Unsworth, 2017). The strong predictive ability of this simulator for determining fitness to drive and its clear connection to driving performance and driving skills make it a strong candidate to be widely and consistently used by both generalists and OT-DRSs. Additionally, continued and widespread use of this tool would help to further validate and refine the protocol, making it an even stronger and easier to use tool.

While the simulator procedure examined in this study was highly predictive of fitness to drive, the fact that it is not perfectly predictive of fitness-to-drive also supports the complex and expert role of an OT-DRS to consider myriad factors in their assessment, of which an interactive driving simulator assessment may be one part. An OT-DRS using other assessments and expert observation and clinical judgement skills is still necessary to determine fitness to drive. Despite data and analyses from this study primarily supporting use of this tool by generalists to know when to refer a client to a DRS, there appear to be much broader possibilities for the use of interactive driving simulators in occupational therapy practice. A specialist with a greater knowledge and understanding of the simulator will likely be able to gain as much or more information from observing clients as they do from the numerical results received at the end of each level. While being an assessment of multitasking, there are also many other underlying skills needed to be successful, just as in the occupation of driving. One example is that an OT-DRS would likely quickly be able to pick up on a visual field cut, inattention, or neglect by observing which 'E's a client is responding to. Impulse control can also be seen by how well a client suppresses the urge to immediately respond to the backward, distractor 'E's.

The levels used in this study could also be used by both OT-DRSs and generalists in the form of an intervention instead of as an assessment. The results of this study support that success on the simulator levels is correlated with fitness-to-drive, leading to the conclusion that the simulator uses skills which are important to and translate directly to driving. Occupational therapy practitioners can therefore consider using this tool in intervention sessions targeting multitasking, visual scanning, attention, impulse control, and more.

Limitations

Due to the procedure of discontinuing trials after failing a single level three times, comparing performance between groups on all but the first level was not able to be properly carried out. Discontinuing trials was appropriate to prevent frustration and maintain the dignity of participants who were struggling with the levels, but it also skewed the data. Those that struggled most on the simulator levels did not have data for the latter levels, so averaging a group's performance more specific to a single level is biased toward high-performers and is not representative of the group. Instead of comparing performance on individual levels, performance over the course of the trials was considered instead by comparing which levels participants passed and failed.

Another limitation of this study was that not every participant was able to complete a comprehensive driving evaluation or an on-road driving assessment. Every medically at-risk participant did receive a comprehensive driving evaluation, and some older healthy controls had an on-road driving assessment, but the young and middle-aged participants were considered fit-to-drive based on self-reported status as a licensed driver and good physical and cognitive health. Only one older adult in the healthy control group did not do the on-road driving assessment and was considered fit-to-drive by default. Taking every young and middle-aged participant on the road for a driving assessment would have significantly increased the cost and time needed to complete the study for likely little to no change in whether participants were considered fit-to-drive.

Another, less significant limitation of this study was the sample population. A significant number of participants were from East Carolina University, a population of individuals more highly educated than the general population. Additionally, geographically most participants came from eastern North Carolina. While it would have been ideal to have a more representative group of participants, the effects of this limitation are likely reduced by the study looking primarily at the discrete skills of multitasking as it relates to fitness-to-drive. Additionally, the study used an interactive driving simulator, a novel tool which participants were not experienced with prior to the study.

Future Research

Future research could address the first limitation discussed above. Increasing the detail with which participants' scores on each level could be compared would likely lend to a more specific and useful tool, especially for driver rehabilitation specialists who are considering many complex factors and could benefit from a higher level of detail. This would require all participants to complete each level to the best of their ability regardless of their performance on previous levels.

Future research could also explore the use of these levels as interventions for assisting participants with regaining the skills necessary to again be considered fit-to-drive. The future study could build on this study's conclusion that the interactive driving simulator levels used appear to require skills which translate into fitness-to-drive as reflected by the statistically significant connection to simulator performance.

Another separate study or part of a different future study could attempt to quantify participants' perceptions of the interactive driving simulator, the levels, the experience, and more. This could further bolster the literature behind perceptions of these relatively new tools and be used by generalists and specialists to support funding requests to obtain them.

Summary

The primary purpose of this study was to evaluate the use of an interactive driving simulator assessment of multitasking as a tool to predict fitness to drive. The performance of medically at-risk adults and healthy adult controls on the simulator were also evaluated and compared. The results showed that performance on the interactive driving simulator appeared to be strongly correlated with fitness-to-drive. Additionally, there was a significant difference in simulator performance between the medically at-risk group and the healthy control group. The differences between the medically at-risk group and healthy control group were consistent with the literature on multitasking, validating the DriveSafety™ FOD task protocol as an assessment of multitasking. Because the DriveSafety™ simulator had a strong, but not flawless, ability to predict fitness to drive, it may be a useful tool for generalist occupational therapy practitioners to use when deciding to refer a client to a driving rehabilitation specialist (DRS). There are many possibilities for interactive driving simulators in the fields of driving and occupational therapy to explore further.

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APPENDIX A: IRB APPROVAL LETTER

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 Amendment Approval

From: Biomedical IRB
To: Anne Dickerson
CC:
Date: 8/5/2022
Re: Ame2_UMCIRB 20-002156
UMCIRB 20-002156
Norms Scanning Task on Drive Safety simulator

Your Amendment has been reviewed and approved using expedited review on 8/4/2022. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a Final Report application to the UMCIRB prior to the Expected End Date provided in the IRB application. If the study is not completed by this date, an Amendment will need to be submitted to extend the Expected End Date. The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Ad for email(0.01)	Recruitment Documents/Scripts
Consent(0.01)	Consent Forms
Revised Drive Safety Directions(0.04)	Clinical Investigators Brochure

Removing Emily Mitchum from the study team.

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

APPENDIX B: DIRECTIONS FOR DRIVESAFETY™ SIMULATOR

DIRECTIONS for Drive Safety Simulator

Instructions in black print (and red) are for the tablet controlling the simulator. Blue is what to say to participant.

Step 1: Set up a chair (without wheels) in front of the simulator, tablet for your operation and turn on the drive safety simulator. Find the Category: **FOD: Advanced category**. Use the buttons to go *Forward*.

Step 2. Start the tasks.

We are going to use a driving simulator to assess your ability to scan the environment and multi-task. Sit on the chair with your foot on the accelerator. Check to make sure you are at a comfortable distance. As we get the simulator ready, don't touch the steering wheel until we tell you.

- *We are going to do a variety of tasks with each getting more challenging activities. There are 5 actual tasks, but we may repeat some of the tasks for practice if you have any trouble learning the task. You may not get to Task 5.*

Task 1. FOD – no changes to the settings.

- *Do you see the car on the road in front of you? Once we start, the car will move and **always** stay in front of you. Your vehicle is on **cruise control** and will stay at 35 miles an hour. When you see the car's brake lights light up, I want you to hit the brake with your right foot. Do you understand?*

Press forward

- *Now do you see all the Es on the three screens? Each of these Es will pop up on the screen, one at a time for 2 seconds. When you see an E, you hit the red button on the steering wheel. If the E is on the right side, you press the right sided button, if the E is on the left side, you hit the red button on the left.*
- *You do need to steer and try to stay in the middle of the lane.*

[Show the buttons and make sure the individual understands the right and left side of the screens for the Es.]

- *Do you have any questions? Remember to hit the red button when you see an E and hit the brake when you see the car's brakes. Put the car in DRIVE.*

Briefly go over the results. Only got on to Task 2 if the participant gets at least 80% on the Brake and Target Scores. If not, repeat the Task 1.

Task 2. Driving Parameters: Cruise off, auto-steering off

- *Now we are going to do the same thing. However, this time you will need to use the gas pedal, it is* ***not*** *on cruise control. Try to drive at 35 miles an hour.*
- *You will be using the gas pedal to drive and will need to brake when you see the vehicle ahead brake. You need to still press the red button when you see the Es. The vehicle ahead will always be in front of you.*
- *Do you have any questions? Okay let's go. Put the car in DRIVE.*

Photo is the same as above; same task but the cruise is off.

Briefly go over the results. Only go on to Task 3 if the participant gets at least 80% on the Brake and Target Scores. If not, repeat the Task .

Task 3. Driving Parameters: Cruise off, auto-steering off, Target Parameters/ distractors at E, 1

- *Now we are going to do the same thing. However, this time sometimes the 'E' will be facing backward when it pops up. When you see a backward 'E' do not hit the red button; only hit the red button when you see a forward-facing 'E'.*

- *You will be using the gas pedal to drive and will need to brake when you see the vehicle ahead brake. You need to still press the red button when you see the forward-facing Es. The vehicle ahead will always be in front of you.*
- *Do you have any questions? Okay let's go. Put the car in DRIVE.*

Photo is the same as above; same task but the cruise is off.

Briefly go over the results. Only go on to Task 4 if the participant gets at least 80% on the Brake and Target Scores. If not, repeat Task 3.

Task 4. Driving Parameters: Cruise off, auto steering off, Speed 45 mph Target Parameters/distractors at E, 1 and add Third row on. Submit.

- *Now, we are going to do the next task. It will a similar task. You will brake when you see the brake lights of the car ahead and you will need to use the gas pedal to try to keep your speed at 45 this time.*
- *You will also be pressing the red button when you see the Es on the screens, but there are still going to be some **Es facing backward,** and there will be more of them on the screen. When you see those backwards Es, remember do **not** press the red button.*

Briefly go over the results. Only go on to Task 5 if the participant gets at least 80% on the Brake and Target Scores. If not, repeat the Task 4.

Task 5. Driving Parameters: Cruise off, auto steering off, Target Parameters/distractors at 0, Speed up to 45, Rear view Mirror and Submit.

- *The next task will include the same elements, you will brake when you see the brake lights of the car ahead and you will need to use the gas pedal to keep your speed up to 45 miles per hour. You will also be pressing the red button when you see the Es on the screens and there will be* ***no distractors****.*
- *When you brake, a number will appear in the review view mirror, I want you to* ***call out*** *the number that will appear in the rear-view mirror.*

Briefly go over the results. Only go on to Task 6 if the participant gets at least 80% on the Brake and Target Scores. If not, repeat the Task 5.

Task 6. Driving Parameters: Cruise off, auto steering off, Target Parameters/distractors at E1, Speed up to 45, All three mirrors and Submit.

- *The next task will include the same elements, you will brake when you see the brake lights of the car ahead and you will need to use the gas pedal to keep your speed up to 45 miles per hour. You will call out the numbers seen on all three mirrors.*

Briefly go over the results. They may only attempt this task once.

APPENDIX C: PHOTO OF DRIVESAFETY™ SIMULATOR

(DriveSafety)