THE INFLUENCE OF VISUAL SUPPORTS ON DRIVING PERFORMANCE IN NOVICE DRIVERS WITH AUTISM SPECTRUM DISORDER

by

Haley Poythress

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Thesis Director: Anne Dickerson, Ph.D., OTR/L, SCDCM, FAOTA, GSA

Department: Occupational Therapy

Rationale: Driving is a valued instrumental activity of daily living (IADL) that signifies a transition to increased independence. However individuals with Autism Spectrum Disorder (ASD) obtain their license at a lower rate than typically developing peers due to differences in motor skills, visual processing, cognition and confidence. Visual supports are objects that provide visual and/or tangible information to improve an individual's understanding of any given activity or context. As an intervention tool to improve functioning, visual supports are included in the ASD guidelines for facilitating attention, improving quality of movement, and increasing predictability to reduce anxiety. However, while there are multiple visual supports in the driving environment, the strategy of using visual supports for driving intervention with autistic individuals has not been addressed in the literature. **Purpose:** To examine the effectiveness of using a visual support strategy, an interactive app called *Drive Focus®* was used as an occupational therapy intervention to improve driving performance in autistic individuals. Specifically, the research questions were: Does the use of a visual support intervention improve overall driving performance of ASD individuals as measured by (1) a standardized occupational therapy assessment of driving performance and (2) improved speed and accuracy of hazard recognition (critical and non-critical) by utilizing eye tracking technology. **Design:** A pre- and post-test design. **Participants:** Participants were 14 individuals with ASD between the ages of 14 and 30 (M = 19, SD = 4.33) with various driving experience. **Methods:** Each participant wore the *Tobii Pro* eye tracking glasses that track and record pupil glances at specific hazards on an interactive driving simulator. Outcomes include *average fixation duration* (how long they look at a hazard), *number of fixations* (how many times they see a hazard), and *time to first fixation* (how long it takes to see a hazard) for critical and non-critical items during four simulated driving scenarios. Each participant drove two scenarios for the pre-test and two different, but matched scenarios for the post-test. All scenarios were randomly assigned and counterbalanced in terms of critical hazards and high inter-rater reliability was achieved (α = .953). Between the pre- and post-tests, all participants completed six 45-minute intervention sessions utilizing the visual support *Drive Focus*®. **Analysis:** Driving performance was measured by a standardized occupational therapy driving performance checklist and eye tracking technology. Eye tracking outcomes were recorded and imported into the *Tobii Pro* Analysis software before being analyzed using repeated measures ANOVAs along with the *Performance Analysis of Driving Ability* (*P-Drive*) results. **Results:** Participants significantly increased their *maneuvers* driving performance scores in the *urban* scenario and *orientate* scores in the *rural* scenario. Moreover, the *average duration of fixation* toward *signs* increased in the *rural* scenario and toward *pedestrians* in the *urban* scenario. However, overall driving performance did not show statistically significant change. **Discussion:** Findings from this study suggest visual supports may be an effective occupational therapy intervention tool for specific aspects of driving performance. These results align with previous literature suggesting visual supports can improve attention allocation and movement deficits in this population. The positive influence varied based on driving condition (i.e., *urban* and *rural*) with *rural* improvements being related to

critical cues in the environment (i.e., *signs*) and *urban* improvements directed toward critical hazards (i.e., *pedestrians*). However, regardless of condition, the intervention may have given participants the ability to allot more visual attention to critical items as it pertained to the driving environment. With more attention directed toward processing hazards, driving performance was improved. Still, due to the small sample size further research needs to be completed to help determine the efficacy of using visual supports to improve driving performance in this population. Nevertheless, practitioners may use visual support interventions to address deficits in IADL performance for individuals with ASD, although different visual supports may provide different benefits to clients.

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APPROVED BY:

DIRECTOR OF
THESIS: ______________________________
Anne Dickerson, Ph.D., OTR/L, SCDCM, FAOTA, GSA

COMMITTEE MEMBER: ______________________________
Lauren Turbeville, OTD, OTR/L

COMMITTEE MEMBER: ______________________________
Lynne Murphy, EdD, OTR/L

COMMITTEE MEMBER: ______________________________
Xiangming Fang, PhD

CHAIR OF THE DEPARTMENT
OF OCCUPATIONAL
THERAPY: ______________________________
Denise Donica, DHSc, OTR/L, BCP, FAOTA

DEAN OF THE
GRADUATE SCHOOL: ______________________________
Kathleen T. Cox, PhD

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Chapter 1: Introduction

Driving is a key life skill that often signifies a transition to increased independence (Chee et al., 2017; Dickerson et al., 2011). While there are many potential positive and negative consequences of obtaining a driver's license, being able to drive gives individuals increased independence and convenience of transportation. Each of these benefits increase the likelihood of participation in work, educational, leisure, and social occupations which have been well documented as important for well-being (Chee et al., 2017, 2014). Moreover, driving has been shown to help young adults maintain self-esteem (Chee et al., 2014). It is evident that there are many positive consequences of driving, however, there can be negative consequences of obtaining a driver's license. Specifically, motor vehicle crashes are the leading cause of death for teenagers (Monahan et al., 2013). Regardless of the dangers of driving, the many benefits may improve occupational engagement and self-esteem of drivers.

Driving and community mobility is an occupation classified as an instrumental activity of daily living (IADL). IADLs are "activities that support daily life within the home and community" (American Occupational Therapy Association [AOTA], 2020, p. 30). This classification supports the likelihood that obtaining a driver's license increases participation in various occupations and therefore improves individual's well-being. As an IADL, driving and community mobility involves the use of both public and private transportation (AOTA, 2020). Both aspects of this occupation are crucial, however, public transportation may not be available to all individuals, especially those in rural communities. Furthermore, independent driving inherently provides more convenience to drivers. Thus, it is evident that obtaining a driver's license has many implications for not only maintaining an individual's self-esteem but improving their overall well-being through engagement in occupations.

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by two core symptoms: repetitive behaviors or interests and social communication or interaction deficits. Due to the fact that ASD exists on a spectrum, symptoms and severity of symptoms vary greatly between individuals (American Psychiatric Association [APA], 2013). The DSM-5 categorizes this variation of symptoms into three levels differentiated by need of support. Individuals classified as Level 3 require “very substantial support”, Level 2 require “substantial support”, and Level 1 “require support” (APA, 2013). Colloquially, those individuals classified as severity level 1 are referred to as having high functioning Autism Spectrum Disorder. These individuals frequently succeed in higher education and obtaining and maintaining a job (Howlin, 2000). Of the ASD population, individuals classified as severity level 1 are most likely to obtain a driver’s license. However, high functioning autistic individuals still require assistance with some tasks. In general, autistic individuals obtain their driver’s license at a lower rate than typically developing peers (Chee et al., 2014). This is due to a variety of factors that can influence an individual with ASD’s visual, motor, and cognitive skills.

This variety of deficits autistic individuals experience can influence their ability to obtain a driver’s license (Chee et al., 2017). Due to the importance of obtaining a driver’s license and difficulties autistic individuals have in doing so, this study assessed the effect of visual supports on overall driving performance of autistic individuals.

Chapter 2: Literature Review

Model of Driving Behavior

Driving is a complex task that can be explained as a hierarchical model of driving behaviors (Michon, 1985). The hierarchy begins with operational skill followed by tactical skill and strategic skill (Transportation Research Board, 2016). Operational skills are used to physically operate a vehicle. These skills involve tasks such as turning the steering wheel, using the gas and brake pedals appropriately, and turning wind shield wipers on and off. These skills are typically things that novice drivers think about, but experienced drivers often automatically perform without conscious thought. Tactical skills are used to maneuver the vehicle while interacting with the environment and other road users. These skills are used to follow the rules of the road. For example, tactical skills help determine when to accelerate, when to pass another car, and when it's your turn at a four-way stop. Lastly, strategic skills are utilized to determine driving route (Transportation Research Board, 2016). For example, if a road is closed strategic skills allow the driver to find their way home via a different route. All three types of driving skills can occur at the same time. Proficient driving and utilization of all three skills within the context of driving requires visual skills, motor skills, and cognitive skills including executive functioning (Chee et al., 2014; Monahan et al., 2013).

To accomplish this simultaneous use of skills drivers must recognize several different types of hazards and cues. The first are the critical cues defined, for this study, as objects that provide information about driving expectations and performance. These include regulatory signs (excluding stop signs) and speed limit signs as well as checking one's mirrors and speedometer. Second, non-critical hazards are, hazards that should be observed to maintain safe, effective driving but do not necessarily require an immediate response. This includes hazards such as oncoming traffic, parked or stopped vehicles on the shoulder, or pedestrians on the sidewalk. Lastly, critical hazards are hazards that are essential for the driver to observe and respond to appropriately. Critical hazards include traffic lights, stop signs, pedestrians or any other roadway obstruction, and other vehicles merging or pulling out in front of the driver. Each type of hazard and cue provides crucial information for the driver to inform decision-making that facilitates safe and effective use of all driving skills.

Driving and ASD

Since driving requires a complex combination of skills, many aspects of ASD can influence driving performance (Chee et al., 2014; Monahan et al., 2013). Visual skills are required to see signs, signals, and other drivers on the road (Monahan et al., 2013). Motor skills are crucial for all aspects of driving to maneuver the vehicle and manipulate different aspects of vehicles such as air conditioning or radio volume (Monahan et al., 2013). Cognitive skills, and more specifically executive functioning skills, are required to make quick decisions and perform tasks simultaneously within the rapidly changing and unpredictable driving environment (Chee et al., 2014; Monahan et al., 2013). The intricate use of visual, motor, and cognitive skills to drive successfully creates critical implications for driving performance in populations with deficits in these areas.

Autistic individuals, regardless of severity level, have many deficits that can increase driving difficulty. These deficits include decreased executive functioning and difficulties making quick decisions under changing situations, decreased motor coordination, and attention allocation difficulties (Breslin & Rudisill, 2011; Chee et al. 2014; Gowen & Hamilton, 2013; Hewitt, 2011; Rutherford et al., 2020).

Motor Function

Motor coordination is crucial for optimal driving performance (Chee et al., 2014, 2017; Patrick et al., 2018). Recent research has found that autistic individuals often have motor impairments, specifically including impairments in balance, gait, coordination, praxis/motor planning, and interpersonal synchrony (Kaur et al., 2018). These kinds of deficits could contribute to decreased driving performance. Specifically, praxis deficits could impact one's ability to perform tactical skills while driving. Whereas coordination and motor planning deficits could impact an individual with ASD's ability to maneuver a vehicle at the operational level. In fact, a study conducted by Chee et al. (2017) found that autistic individuals performed maneuvering of a vehicle more poorly than typically developing peers. This study included 21 typically developing drivers and 16 drivers with ASD. Each group participated in a 25 minute standardized drive in their own vehicles with researchers seated in the back seat. Participants were scored based on a driving performance checklist and the *Performance Analysis of Driving Ability* (*P-Drive*)*,* a standardized occupational therapy assessment. Through the *P-Drive*, ASD drivers performed more poorly in the *maneuver* category. More specifically, steering at intersections was observed as "hesitant and slow" (Chee et al., 2017, p. 2665).

Visual Processing

Attention allocation difficulties produce other challenges for autistic individuals. Driving presents a constantly changing environment with many important and unimportant stimuli. Difficulty allocating attention to important stimuli (e.g. pedestrians, other vehicles, traffic signals) can result in catastrophic consequences. When driving, allocating attention is most commonly determined through visual scanning and appropriate responses to visual stimuli. Several studies have found that people with ASD have more difficulty with visual attention, visual scanning, eye gaze and duration, and hazard perception within and outside of the driving environment (Bishop et al., 2017; Classen, Monahan, & Wang, 2013; Grynszpan & Nadel, 2015; Guillon et al., 2014; Reimer et al., 2013; Sheppard et al., 2010; Wang et al., 2015). Moreover, Underwood (2007) found that visual scanning and attention was the differentiating factor between novice and experienced drivers. More specifically, when compared, experienced drivers visually scan their environment more extensively based on road complexity. However, novice drivers do not alter their visual scanning in response to roads that demand increased monitoring.

A study conducted by Reimer et al. (2013) used eye-tracking software and found that autistic individuals had a higher eye gaze and shift of attention away from the vehicle in front of them when cognitive demand increased while driving on a simulator compared to typically developing drivers. These participants were found to have an eye gaze fixated 44% higher than typically developing peers, making ASD participant's eye gaze more focused on the horizon than on the road directly in front of them. This also provides evidence that autistic individuals shift their attention to a less complex and stimulating area of the visual field when cognitive demand is increased (Reimer et al., 2013).

Wang et al. (2015) used images of natural scenes including a desk, sports games, items on a table, tourists standing in front of a sign, and more to analyze the visual attention of individuals with ASD. When comparing autistic individuals to matched controls this study found a stronger central bias with increased attention to low-level saliency and decreased attention to semantic-level saliency. This suggests that individuals with ASD tend to look at the center of the visual field, background textures, and pixel-level features rather than objects or more abstract meaning within images. The impact of these differences for people with ASD can greatly influence hazard detection while driving because driving hazards are most commonly objects or other people (e.g. oncoming traffic, pedestrian, etc.) that come from outside of the central visual field and become increasingly critical as they near. Moreover, these findings imply sensory processing differences found in this population may influence individuals' typical visual attention.

Hazard Detection. Other visual processing deficits that are relevant to driving are evident through differences in hazard detection. Most significantly, Sheppard et al. (2017) found that autistic individuals are slower to fixate on hazards compared to typically developing peers. This study controlled for differences in eye gaze found in this population by having both autistic and typically developing participants look at a specific dot directly in the middle of the screen until a hazard was detected. After detection the participant was to look at the hazard and push a button. Time to first fixation, spread of fixations, and fixation duration were all recorded with one hazard per recording. Although this difference of slower fixation within the autistic population was statistically significant, Sheppard et al. (2017) suggests that these differences are too small and therefore should not have a negative impact on overall driving ability. Moreover, it is important to note there were no significant differences in reaction time after first fixation between groups (Sheppard et al., 2017). This indicates that autistic individuals are slightly slower to notice hazards, but no slower to react after identifying the threat in order to prevent negative consequences.

There is mixed research regarding differences amongst autistic individual's ability to recognize social hazards (i.e. pedestrians and cyclists) compared to other hazard types (i.e., cars pulling out). In the previously discussed study, Sheppard et al. (2017) found there was no effect dependent on hazard type (i.e. social hazard v. not social hazard). However, according to multiple eye tracking studies autistic individuals spend less time looking at social stimuli (i.e.

people and faces) than typically developing peers in natural contexts (Guillon et al., 2010; Sheppard et al., 2010). Although driving was not analyzed in Guillon et al.'s (2010) research, a study conducted by Sheppard et al. (2010) found participants diagnosed with ASD or Asperger syndrome identified fewer social hazards compared to typically developing participants.

Each of these visual processing differences autistic individuals experience have the potential to make learning to drive more difficult and potentially dangerous. Differences in eye gaze and the tendency to shift attention away from other vehicles and/or important hazards could have catastrophic consequences when driving (Reimer et al., 2013; Wang et al., 2015). Moreover, these differences combined with slower time to first fixation mean autistic individuals likely may not even see hazards at all (Sheppard et al., 2017). However, there is no difference in hazard reaction time after first fixation emphasizing the importance of focusing on hazard detection and recognition with the ASD population.

Cognition

Executive functioning is a specific cognitive ability that is especially critical for driving performance as it encompasses simultaneously using psychomotor and cognitive skills (Tsatsanis, 2005). Autistic individuals have been found to have deficits in executive functioning, and perform more poorly than typically developing peers while driving in unexpected circumstances (Tsatsanis, 2005). According to Tsatsanis (2005), this decrease in executive functioning impacting complex, everyday tasks has been found throughout the literature in traditional and modified executive functioning assessments for all levels of ASD. More specific to driving, drivers with ASD have difficulties making quick decisions under changing conditions (Hewitt, 2011). Due to the unpredictable environment of on-road situations this has significant implications for driving performance of autistic individuals. However, this is not the only deficit with severe implications. A study conducted by Cox et al. (2015) compared 12 new drivers without ASD, eight new drivers with ASD, and 16 experienced drivers without ASD while they drove on a driving simulator. Researchers measured a variety of factors including, but not limited to, individual's attitudes toward driving, eye-gaze, and driving performance. They found that individuals with ASD showed a more significant decline in driving performance than typically developing populations when driving involved a working memory task like following directions. This finding suggests several diverse cognitive challenges (e.g., sound system manipulation, GPS directions) can have negative implications on driving performance for autistic individuals, especially when driving to unfamiliar locations.

Confidence

Driving independently can initially be a daunting task for anyone, but it is evident that individuals with ASD have more challenges to overcome than typically developing populations. In a study conducted by Ross et al. (2017) parents of people with ASD reported their children as having more negative thoughts than positive thoughts about driving. Another study reports that some individuals with ASD prefer other modes of transportation (e.g., bus, train, or walking) over driving due to slightly heightened anxiety (Chee et al., 2014).

However, safe and low-threat practice of driving, as in driving simulation, has been found to decrease negative attitudes toward driving. Ross et al. (2018) examined negative attitudes toward driving through the *Driving Attitude Scale Parent-Report* of 66 novice drivers with ASD and 166 neuro-typical novice drivers. All drivers were randomly assigned to receive no special instruction or 8-12 virtual reality driving simulation trainings. A significant decrease in negative attitudes of 31.7% ($F = 12.16$, $p - .001$) was found after novice ASD drivers participated in the virtual reality driving simulation training intervention (Ross et al., 2018).

Despite these various difficulties people with ASD can, and often do, obtain a driver's license. In fact, research supports drivers with ASD perform better than typically developing peers for rule-following within the context of driving (Chee et al., 2017). In this study, 16 drivers with ASD and 21 typically developing peers were observed driving a standardized on-road route using the driving performance checklist and *Performance Analysis of Driving Ability* by an occupational therapist. Increased rule-following found in this study includes following speed limits, using indicators, checking for cross-traffic and overall exhibiting less risky driving behavior. In another study conducted by Patrick et al. (2018), 50 young adults with ASD and an equal group of typically-developing peers were recruited to assess driving performance and the relationships between level of driving experience across different driving environments. Variability in speed and lane positioning was determined by calculating the standard deviation from the participant's speed divided by the average speed and standard deviation from center of lane respectively. This study reported increased speed and lane positioning variability in autistic individuals when comparing unlicensed drivers with and without ASD. The same finding was not supported between licensed drivers with and without ASD. The difference in findings between licensed and unlicensed drivers supports the idea that driving is an abstract concept for novice drivers that becomes more concrete with practice over time. The idea that ASD populations perform rule-following better than typically developing peers can significantly improve driver safety and driving performance. However, acquiring the skills necessary to maneuver a vehicle can provide unique challenges for this population.

Visual Supports

Visual supports are objects that provide visual and/or tangible information to improve an individual's understanding of any given activity or context (Rutherford et al., 2020). People use visual supports every day such as calendars, restroom signs, and graphs (Rao & Gagie, 2016). These visual supports help people understand and adhere to a schedule, orient themselves in their environment, or understand information; therefore facilitating an individual's functional abilities. Visual supports are a critical part of driving. For example, road maps and/or Global Positioning System (i.e. GPS) software are considered visual supports that many individuals use while driving at some time or another as a support for their performance. These supports assist individuals with the strategic skills when driving to an unfamiliar place or when navigating complex driving situations. Moreover, there are visual supports built into the context of driving to facilitate operational skills. These include stop signs, traffic lights, and arrows throughout the environment. These visual supports facilitate individuals' functioning within the context of the IADL, driving.

As mentioned, everyone uses visual supports such as a GPS and/or road maps to facilitate strategic skills while driving and signs or traffic lights to facilitate the operational skills. However, most populations do not use visual supports to facilitate the tactical skills needed to drive effectively. Due to the differences evident across the literature regarding autistic individuals' ability to drive, they may benefit from visual supports to improve tactical skills more so than other populations.

As stated, there are many different types of visual supports that each serve different purposes. The most widely known visual supports for individuals with ASD include social stories, picture schedules, and the *Picture Exchange Communication System®* (Rao & Gagie, 2016). Social stories explain social situations while picture schedules assist individuals with transitioning between activities by giving them a visual of tasks and the order in which they occur. The *Picture Exchange Communication System®* is a picture-based communication board (Rutherford et al., 2020).

Video prompting is another type of visual support in which a video is utilized to achieve the same result of providing visual information to the user (Van Laarhoven et al., 2010). Van Laarhoven et al. (2010) found that video prompting was slightly more effective than picture prompting in improving the percentage of independent correct responses during folding laundry and meal preparation (IADL occupations) for two autistic adolescents. In the same study, video prompting was also found to be more time efficient to create and prepare than picture prompting. However, this topic has a lack of further research and this study only included two participants. Nevertheless, there is little doubt that varying types of visual supports have different strengths, weaknesses, and purposes that are crucial to consider when selecting which type to utilize.

Visual supports are recommended in the ASD clinical guidelines (Subramanyam et al., 2019). In a scoping review Rutherford et al. (2020) reported the use of visual supports (e.g. visual schedules, timers, environmental labelling, choice, boards, visual communication supports, etc.) in the classroom improved independence, reduced anxiety, and increased "on task" positive behaviors for autistic individuals. Pierce and Schreibman (1994) found that using visual supports decreased stereotypical behaviors during completion of activities of daily living and IADLs. This was found with three participants in which picture prompts were utilized to address three client-centered target tasks for each client. Tasks included were IADLs such as setting the table, doing laundry, and making lunch. The use of visual supports increased each participants' on-task behavior and decreased inappropriate behavior during task completion. Although there is limited current research on the overall effectiveness of visual supports, the published research supports the benefits of visual supports within the ASD population for a variety of activities including IADLs.

Important Aspects of Visual Supports

Visual supports assist autistic people in many ways. For example, in a scoping review conducted by Rutherford et al. (2020) findings reported that using a type of visual support called a visual schedule to facilitate access and understanding of a variety of situations was successful in increasing predictability, and therefore decreasing anxiety, of the situations for autistic individuals. Similarly, after reviewing relevant literature Rao and Gagie (2006) claim in their textbook that visual supports facilitate and encourage individual's ability to focus on a message and assist in making abstract concepts more concrete.

Finally, a study conducted by Breslin and Rudisill (2011) used a norm-referenced gross motor development assessment and found that the use of visual supports improved the quality of movement scores for autistic children. This study had 22 participants with ASD complete the Test of Gross Motor Development (TGMD) 2 under three different randomly-assigned and counterbalanced conditions including traditional protocol, picture task card protocol, and picture activity schedule protocol. The condition indicated the level of support present during the TGMD-2 administration. In the traditional protocol condition no visual supports were utilized. The picture task card protocol included the use of individual line drawings of the tasks for TGMD-2 items presented individually. While the picture activity schedule protocol used line drawings of the items fixed on a poster in the order they were to be administered. In both conditions that utilized visual supports (picture task card and picture activity schedule protocol) verbal instruction was minimized and all visual supports were used before the participant completed the test item and were removed prior to scoring of the item. It is evident through the results of this study that the use of visual supports significantly improved quality of movement for gross motor actions.

However, not all visual supports are created equal. In order to be beneficial visual supports must be accessible, participation-focused, individualized, consistent, and include information and teaching methods (Rutherford et al., 2020). For example, if visual supports are inconsistent they can introduce more confusion and decrease predictability of a task, which could lead to heightened anxiety. If they are not accessible or do not include pertinent information to the task there is no benefit of task participation or performance. Participation-focused and individualized visual supports that utilize teaching methods ensure the client is engaging with the visual support and gaining as much as possible from it. All of these aspects play a crucial role in the effectiveness of visual supports and should be considered when designing or selecting supports for an individual, group, or population.

Visual Supports and Driving

The benefits of visual supports on facilitating attention, improving quality of movement, and increasing predictability to reduce anxiety could have a profound impact on autistic individuals' driving performance. Driving requires attention to a wide variety of stimuli that are constantly changing. Visual supports have been found to improve people with ASD's ability to focus (Rutherford et al., 2020; Pierce & Schreibman, 1994). This could minimize attention allocation difficulties often found in this population. Quality of movement deficits have also been found to be positively impacted by visual supports (Breslin & Rudisill, 2011). This could improve the operational and tactical levels of driving behavior for individuals with ASD. Lastly, visual supports may decrease the heightened levels of anxiety individuals with ASD experience regarding driving. Despite all of these potential benefits, there have been no studies conducted on the efficacy of visual supports as a driving intervention.

Potential Visual Support Intervention

Drive Focus® (Driver Rehabilitation Institute, Inc., 2020a) is an application (app) that was created to improve both hazard recognition and visual search skills by training users to identify important stimuli in the order of priority through the use of interactive video software (Monahan et al., 2020). Important stimuli include all roadway signs, traffic lights, other vehicles and pedestrians (Monahan et al., 2020). The interactive video software also has qualities that could make it a useful visual support for autistic individuals. In fact, *Drive Focus*® encompasses all of the evidence supported qualities of visual supports that improve varying aspects of activity performance.

Specifically, these qualities include accessibility, participation-focus, individualization, consistency, and utilization of information and teaching methods. The interactive video technology of the *Drive Focus*® app provides ample information on critical items (i.e., hazards) in the training section and utilizes teaching methods that are focused on participation to assist people in identification of important stimuli. These methods include immediate visual and auditory feedback as well as numeric feedback regarding performance. Moreover, the *Drive Focus*® app is relatively inexpensive and accessible. At the time of this study downloading the app cost approximately $12.99 to install on a wide variety of electronic devices. *Drive Focus*® is individualized in that there are different levels of difficulty and the app will record each individual's progress throughout their progression. However, each individual who engages with the app is participating in the same instruction making it both individualized and uniform across participants. All in all, the *Drive Focus*® app has the qualities of a beneficial visual support and therefore has a high potential of improving driving performance specifically for autistic individuals.

Preliminary Efficacy. Last year Monahan et al. (2020) conducted a usability evaluation in which both typically developing and autistic individuals provided feedback for *Drive Focus*® in four rounds. This resulted in a significant number of changes to the app that were all approved by occupational therapy certified driving rehabilitation specialists (Monahan et al., 2020). One of the most notable changes from this process was a decline in comments regarding clarification or wording for the ASD participants (Monahan et al., 2020).

A pilot efficacy study of *Drive Focus*® as an intervention was conducted with 39 typically developing participants in 2018 (Alvarez et al., 2018). Participants were between 16 and 22 years old, had a valid driver's license or leaner's permit, were able to read and comprehend English, and were able to travel to the research laboratory for the duration of the study. Participants completed cognitive, motor, and visual assessments before driving a pretest on the simulator. The simulated driving scenario was recorded and a trained, double-blind evaluator scored the visual scanning errors and adjustment to stimuli errors of participants. Following the pre-test, participants partook in six 45-minute sessions over a 9-week period and completed a post-test in the same manner as the pre-test. Researchers found a statistically significant decrease in visual scanning errors ($t(34) = 2.853$, $p = .007$), adjustment to stimuli errors ($t(34) = 3.481$, $p = .001$), and total number of errors ($t(34) = 3.481$, $p = .002$) from pre-test to post-test (Alvarez et al., 2018). Overall, this study exhibits support for preliminary efficacy of *Drive Focus*® as an intervention.

A later study was conducted to determine differences in intervention effectiveness for drivers with and without driving experience (Alvarez et al., 2019). The study consisted of two participants, one novice driver and one learner driver. The novice driver was a licensed driver with three years of driving experience, whereas the learner driver had no driving experience. Pre-test, mid-point (3 weeks of intervention), and post-test (6 weeks of intervention) data was collected by analyzing the number of visual scanning, adjustment to stimuli, and total driving errors during simulated drives. Although the learner driver made more errors compared to the novice driver, both participants experienced a decrease in errors from pre-test to mid-point and post-test. The learner driver demonstrated a 48.5% decrease in visual scanning errors from pre-test to mid-point and a 56.25% decrease from pre-test to post-test. They also demonstrated a 30.8% decrease in stimuli adjustment errors from pre-test to mid-point and a 56.4% decrease from pre-test to post-test. The novice driver experienced a 57.1% decrease in adjustment to stimuli errors from pre-test to mid-point and a 35.7% decrease in visual scanning errors from pre-test to post-test. They demonstrated a 12% decrease in visual scanning errors from pre-test to post-test, but no difference in visual scanning errors was found for the novice driver between the pre-test and mid-point. Overall, this study supports the idea that new drivers benefit more from *Drive Focus*® intervention than experienced drivers do (Alvarez et al., 2019). However, future research is needed to evaluate the validity of this claim and quantify effect sizes.

All in all, *Drive Focus*® is an intervention with high acceptability amongst the ASD population with preliminary efficacy in improving visual scanning errors, adjustment to stimuli errors, and total errors for individuals without ASD.

Eye Tracking Technology

Eye-tracking technology is an established research tool that has contributed to many aspects of clinical settings including indication of clinical skills, training solutions, feedback and reflection (Ashraf et al., 2018). Wearable eye-tracking technologies use infrared LED lights that illuminate the eye and video-based tracking to record images of the illuminated eye. This technology can provide both qualitative and quantitative information. Qualitative information is derived by replaying and analyzing eye-tracking technology videos and coding them accordingly. Quantitative information can be obtained from the eye-tracking software itself including total *fixation duration, fixation count,* and *time to first fixation*.

Research with eye tracking software and Autism Spectrum Disorder has been done for a variety of reasons including to analyze social behavior, design a variety of augmentative and alternative communication strategies, and to analyze driving behaviors. Several of the studies discussed above used eye tracking including Wang et al. (2005) that found autistic individuals tend to focus on background textures in the center of visual fields; and Reimer et al. (2013) that found differences in eye gaze for this population. Additionally, Sheppard et al. (2010; 2017) found that this population is slower to fixate on hazards and may or may not have differences in recognizing social hazards as described above. These studies demonstrate significant differences found between typically developing populations and autistic individuals using eye-tracking across environments (i.e. natural contexts and driving).

In the Reimer et al. (2013) study, participants included 10 males with ASD and age matched, typically developing peers from ages 18-24. Participants drove on a simulator in a highway and urban environment with two distracting tasks: a phone task and an auditory continuous performance task. Researchers utilized a FaceLAB 5.0 eye tracking system. The participants with ASD had a gaze fixated 44% higher than those without ASD, meaning these participants were less focused on the active road and more focused on the horizon (Reimer et al., 2013). Both groups of participants shifted their attention to the left side of the road when participating in distracting tasks, but only the ASD participants reached a statistically significant difference. Using eye tracking, Reimer et al. (2013) were able to effectively and accurately identify key differences between these populations while driving.

Another study utilized eye tracking technology to compare newly licensed drivers with and without ASD and experienced drivers (Cox et al., 2020). In this study, 20 new drivers and 16 experienced drivers drove both a standardized on-road route and simulated drive. Researchers identified critical visual targets and used a Gazepoint CP3 eye tracker to analyze participant's gaze during eight challenging parts of the simulated drive including "merging into a highway and passing a slow lead car, turning left from a highway ramp, avoiding a motorcycle making a left turn in front of the driver, cresting a hill and avoiding on-coming car, and yielding to a bicyclist at a right turn" (Cox et al., 2020, p. 1261). The eye tracking software tracked general gaze and required a coder, blind to group assignment, to code responses. In this study, there was no difference in the number of critical items viewed or the number of times the speedometer was checked between groups. However, the rater reported feeling less comfortable as a passenger for the new drivers with ASD compared to all other groups (Cox et al., 2020). There are limitations to this study because the eye-tracking technology used required human coding and there was no inter-rater reliability. All in all, utilizing data produced by eye tracking technology may be an effective way to directly and objectively measure eye gaze and has been used in a wide variety of Autism Spectrum Disorder research including driving research (Ashraf et al., 2018; Reimer et al., 2013; Wang et al., 2015).

Through this research it is evident that wearable eye-tracking technology is an established research tool that demonstrates significant differences in visual attention across tasks for the autistic population. Moreover, this technology has been utilized while driving to pinpoint differences and similarities between typically developing and autistic populations similarly as it will be utilized in this study to determine differences pre- and post- intervention.

Summary

In summary, driving is a crucial IADL for encouraging participation in a variety of activities for people with and without ASD. Driving performance for autistic individuals differs from typically developing populations in that rule-following is increased (Chee et al., 2017). However, this population has been shown to have difficulty maneuvering the vehicle, allocating attention to important stimuli, making quick decisions in an unpredictable context, and are often anxious about driving due to decreased visual, motor, and cognitive skills associated with ASD (Chee et al., 2014, 2017; Hewitt, 2011; Monahan et al., 2013; Ross et al., 2018).

Current literature supports that the use of visual supports with effective characteristics that may target specific driving deficits found within the ASD population including motor coordination, attention allocation, as well as the anxiety and concreteness of the task (Breslin & Rudisill, 2011; Rao & Gagie, 2006; Rutherford et al., 2020). Moreover, improving these various aspects could therefore improve overall driving performance (Rutherford et al., 2020). In this study, *Drive Focus®* was selected as a readily available and accessible intervention designed specifically to emphasize visual scanning to assist with hazard detection. Thus, the purpose of this study is to test the impact of using visual supports as an occupational therapy intervention to improve driving safety and performance in autistic individuals. The following questions will be answered:

1. Does the use of a visual support intervention improve overall driving performance of autistic individuals as measured by the *Performance Analysis of Driving Ability* (*P-Drive*)?

2. Does using a visual support intervention improve the speed and accuracy of hazard recognition, both critical and non-critical, while driving for autistic individuals as measured by eye tracking technology?

Chapter 3: Methodology

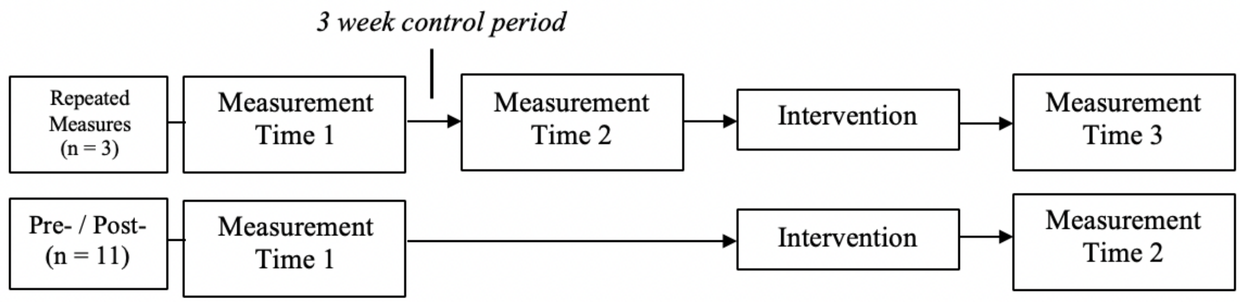
Design

The design was a pre- and post-test design after establishing maintenance of baseline driving performance by utilizing a within-subject repeated measures design with three participants. The three participants were measured three times driving one or two drives (scenarios) on the interactive driving simulator (see Figure 1); time 1 when enrolled, time 2 after a three-week “control” period, and time three after the intervention. The first two measurements were compared and measured for any change in baseline driving performance. For the remaining 11 (80%) participants, only two measurements were utilized as a pre- and post-test design in an attempt to increase sample size. The intervention period was used to examine the extent of change for all participants before and after the visual support intervention (pre- and post-test).

The independent variable was time (pre- or post- intervention). To answer research question one, the participant’s driving performance on the driving simulator was the dependent measure, a total score measured by a standardized observational tool. For the other two research questions, eye tracking technology was used to determine if there is a difference in the number of glances (i.e. *number of fixations*) at critical (hazards) and non-critical hazards (e.g., other vehicles and pedestrians on walkway). Specifically, two percentages of total glances during the simulator drives were utilized. The first percentage compared number of critical items detected by visual fixation to the total number of critical items. While the second percentage compared total number of non-critical items detected to the total number of non-critical items present. Quality of the glances was also compared using the *time to first fixation* and *average duration of fixations* on critical and non-critical items.

Figure 1

Research Design



Participants

The target population was teenagers and young adults with ASD within North Carolina. A total of 14 participants were recruited through convenience/volunteer sampling methods by contacting the Autism Society of North Carolina, Pitt County Public Schools, personal contacts, and emailed advertisements. Inclusion criteria for participants included self-reported diagnosis of ASD, at least 14 years of age to ensure driving is appropriate for the participant, and three years or less of driving experience. Individuals with less than three years of driving experience, regardless of whether they had a license or not, were included because visual supports were expected to improve novice driver's driving performance more than a more experienced driver (over three years). However, due to the measurement of driving performance on a simulator, participants were required to have received a minimum of rules of the road instruction. Exclusion criteria included any other significant diagnoses that could influence driving performance. Approval from the Institutional Review Board of East Carolina University was obtained (see Appendix A) and consent collected before data collection. For participants ages 14 - 17, informed assent from the child and informed consent from the child's parent or guardian was obtained; while informed consent of participants ages 18 and up was obtained. Participants were offered a $20 gift card for each measurement time to compensate for travel to the testing site and time of participation.

Instrumentation

Demographic Questionnaire

A demographic questionnaire was designed to collect information and make comparisons between groups (see Appendix B). The questionnaire included questions regarding driving history and information such as age, ASD diagnosis, and education.

Adolescent/Adult Sensory Profile (AASP)

The AASP (Brown & Dunn, 2002) is a 60 item self-report questionnaire used to evaluate how individuals respond to sensations in everyday life. Sensations evaluated included taste/smell, movement, visual, touch, activity level, and auditory stimulation. Results yielded user's sensory quadrant(s) including low registration, sensation seeking, sensation sensitivity, and sensation avoidance (Brown & Dunn, 2002). This assessment was completed to account for potential differences in autistic individual's typical visual attention such as the tendency to attend to less complex or stimulating areas of the environment such as background textures and the horizon while driving (Reimer et al., 2013; Wang et al., 2015). The AASP scores are later analyzed in terms of their impact on driving performance scores.

This assessment has well established reliability and validity across populations with internal consistency of the quadrants between .66 and .82 (Gándara-Gafo et al., 2019). Moreover, there is strong discriminant validity across populations (Brown & Dunn, 2002). Ermer and Dunn (1997) found that the AASP was an effective way to discriminate between those with Attention Deficit/Hyperactive Disorder (ADHD) and ASD. Another study found that individuals with ASD scored significantly differently on the research version of the Sensory Profile compared to individuals without autism (Watling et al., 2011). These findings support the use of the AASP as a measure of sensory responses for a variety of populations including the autistic population.

Performance Analysis of Driving Ability (P-Drive)

The *P-Drive* (Patomella, 2014) was utilized to measure the dependent variable of change in overall driving performance (see Appendix C; Patomella & Bundy, 2015). The *P-Drive* is a structured assessment with 25 items designed to evaluate safety and quality of driving performance based on observation of both on-road and simulator driving. The items are divided into four subgroups: *maneuver, orient, follow regulations, and attending, acting, and heeding*. Each item was rated by an observer on a scale from one to four. In this scale, one is incompetent and unsafe performance, two is ineffective and risk performance, three is questionable and hesitant performance, and four is good, competent and safe performance (Patomella & Bundy, 2015).

The *P-Drive* has high reliability and validity across the literature (Patomella & Bundy, 2015; Patomella et al., 2010; Vaucher et al., 2015). In one study, conducted by Patomella and Bundy (2015), a Rasch analysis showed strong person response validity with 96% of therapists having responses within the acceptable range for goodness of fit. There is also evidence that the *P-Drive* can separate drivers into more than four categories of driving ability (e.g. competent performance, hesitant performance, ineffective performance, and incompetent performance; Patomella & Bundy, 2015). The reliability coefficient for person separation reliability in a typical population was .92 showing that the *P-Drive* has strong reliability. In another study, a person separation reliability coefficient of .90 was found in populations that had experienced or were experiencing stroke, dementia, or mild cognitive impairment (Patomella et al., 2010). This same study supported the internal validity, internal reliability, and construct validity of the *P-*

Drive for producing a linear measure of driving ability (Patomella et al., 2010; Patomella & Bundy, 2015). Vaucher et al. (2015) found that the *P-Drive* had strong interrater reliability with an intraclass correlation coefficient of .95 (CI 95%). There is evidence that the *P-Drive* has strong internal construct, and person response validity as well as internal reliability and person separation validity. This makes the *P-Drive* a useful measure for analyzing driving performance in an objective manner.

The *P-Drive* is often used clinically to determine individual's ability to drive and allow practitioners to make recommendations. For this reason, cutoff scores must be established. Patomella and Bundy (2015) recommend cutoff scores between 81 and 85 depending on the population and label individuals who scores fall between these as being in the "gray zone". Individuals with these scores should have driving recommendations made based on other factors and clinical judgement. After running a sensitivity and specificity analysis these researchers describe the ideal raw score cutoff at 81 (Patomella & Bundy, 2015). This cutoff score had strong qualities, with a specificity of .92 and a sensitivity of .93 (Patomella & Bundy, 2015). A cutoff score of 81 also had a positive predictive value of .95 and a negative predictive value of .90 (Patomella & Bundy, 2015). This evidence strongly supports the use of the *P-Drive* with this cutoff level (81) to accurately determine one's ability to drive safely and competently. Moreover, this study found that correlation between raw scores and interval measure scores was .88 meaning a sum of *P-Drive* raw scores can be utilized as a valid outcome score.

Equipment

TRAN-SIT®

The TRAN-SIT® (Advanced Therapy Products, n.d.) interactive driving simulator was utilized to simulate on-road driving. The body of the driving simulator mimics a motor vehicle with two side doors that open like typical car doors and adjustable seats with seatbelts on both the driver and passenger sides. The driver's seat is equipped with a steering wheel with a turn signal, gas pedal, and brake pedal along with various buttons to control aspects of the simulation such as when the simulation begins (Advanced Therapy Products, n.d.). Three monitors imitate the windshield and display the driving environment with both side mirrors and a rearview mirror (see Figure 2).

Figure 2

TRAN-SIT Simulator with Screens

Interactive Driving Simulator Software: STISIM OT Drive

STISIM OT Drive software (Systems Technology Inc., 2020) was the software used for the driving simulation. There are several studies that discuss the reliability and validity of driving simulators in general, but Mayhew et al. (2011) and Lee (2003) specifically utilized the STISIM program. The STISIM driving simulator was found to be able to discriminate between different driving levels in terms of errors made (Mayhew et al., 2011). Beginner drivers had an average of 27.5 errors while novice drivers averaged 22.7 errors and experienced drivers averaged only 13.2 (Mayhew et al., 2011). This shows the validity of using a driving simulator as a method of measuring driving performance. In the same study, researchers ranked drivers for on-road driving performance and found these rankings had a significant, positive relationship with simulator performance, showing strong concurrent and discriminant validity (Mayhew et al., 2011) Specifically, detecting hazards in both conditions was positively and significantly related (Mayhew et al., 2011). Another study that used the STISIM driving simulation software found high correlation (.716) between on-road and simulated driving indexes as well (Lee, 2003). Overall, driving performance and simulator performance are significantly related and were found to be reliable and valid measures of overall driving performance (Mayhew et al., 2011; Lee, 2003).

The preprogrammed drives (scenarios) in the STISM Drive software used in this study were approximately five to seven minutes long and included the scenarios specifically called *mountain*, *rural*, *suburban*, and *urban* scenarios. These four scenarios were selected after reviewing all the available options and then paired to create two similar pairs for each measurement time. That is the *urban* and *suburban* scenarios had almost the same number of critical and non-critical items, as did the *rural* and *mountain* scenarios. Four researchers experienced with the driving simulation watched each of the scenarios to count the number of prospective "hazards" and rated the hazard as being a critical hazard, a non-critical hazard (not a hazard per say, but an important item to observe), or a critical cue (important environmental objects to observe (e.g. mirrors, speedometer, and signs). There was high agreement with the differences discussed and determined for each scenario.

The four scenarios were then paired together to make up the "*Urban"* (*urban* and *suburban* matched) and the "*Rural"* (*rural* and *mountain* matched) pairs of preprogrammed driving simulator scenarios. These scenario pairs were randomly assigned and counterbalanced with computer generated groups prior to an individual's participation to prevent practice and order effects. Within-Subject Repeated Measures participants completed comparable scenarios at each measurement time (see Table 1) while pre- and post-test participants completed one scenario from each matched pair at each measurement time (see Table 2).

Table 1

Within-Subject Repeated Measures Design: Simulator Drive Random Assignment and Counterbalancing

Time 1 R Time 2 MS Time 3 U	Time 1 M Time 2 RS Time 3 U	Time 1 S Time 2 UR Time 3 M	Time 1 U Time 2 SR Time 3 M
Time 1 R Time 2 MU Time 3 S	Time 1 M Time 2 RU Time 3 S	Time 1 S Time 2 UM Time 3 R	Time 1 U Time 2 SM Time 3 R

Note: U – Urban Drive, S – Suburban Drive, R – Rural Drive, M – Mountain Drive

Table 2

Pre- and Post-Test Design: Simulator Drive Random Assignment and Counterbalancing

Time 1 RU Time 2 MS	Time 1 MU Time 2 RS
Time 1 RS Time 2 MU	Time 1 MS Time 2 RU

Note: U – Urban Drive, S – Suburban Drive, R – Rural Drive, M – Mountain Drive

Tobii Pro Glasses 3

To quantify changes in visual scanning, the *Tobii Pro Glasses 3* (Tobii Pro, 2021) was used to track participants' eye movements while driving the scenarios. These glasses were worn as typical eyeglasses and utilize five cameras to gather data on eye position and gaze point to collect and record attentional data from the subject's point of view (see Appendix D; Tobii Pro, 2021). For technical specifications see Appendix E (Tobii Pro, 2021). The glasses collected sound recordings, eye and gaze direction, duration of gaze event, fixation points, eye movement, and other data calculated by tracking the reflection of the eyes (Tobii Pro, n.d.). Real-time eye imaging recorded from the glasses can be replayed, exported, and analyzed from the attached memory card (Tobii Pro, 2021; Tobii Pro, n.d.). *Tobii Pro Glasses* have been found to have high precision, binocular accuracy, and detected gaze for large gaze angles across lighting conditions and for a wide variety of target distances according to manufacturers (Tobii Pro, 2018).

Procedure

After obtaining IRB approval, advertisements were sent out to personal contacts, the Autism Society of North Carolina, and Pitt County schools. Participants were recruited both through these advertisements and by word of mouth. If interested, participants contacted the principal investigator (PI) by phone or email. An initial meeting time was scheduled in room 1330 of the Health Sciences Building at East Carolina University's Allied Health Campus. Recruitment and enrollment were ongoing throughout the duration of the study.

At the first meeting the participant signed the consent/assent form and parental consent was obtained as necessary. The demographic questionnaire and AASP were completed and future meetings were scheduled with the researcher.

Driving Simulator and Eye Tracking Collection Process

The participant was then fitted with the *Tobii Pro Glasses 3* and seated in the driving simulator. The PI explained how the simulator works, how to use the controls, and how to respond appropriately in the simulator environment. The participant verbally responded with understanding and the researcher instructed the participant to begin with a "practice scenario".

The practice scenario was a 3-4 minute scenario that included stops and turns offering an opportunity to "practice" and learn the unique environment of the driving simulator. The practice scenario was completed by the participant to ensure they were comfortable on the driving simulator. The researcher ensured the participant was comfortable using the driving simulator and not experiencing motion sickness. Each participant was offered the option of repeating the practice drive if needed to ensure the participant was comfortable. Two participants requested to repeat the practice drive at the initial measurement time. The PI ensured that all participants were negative for simulator sickness before moving to the next step. Once comfort with the simulator was established, the researcher provided the participant instructions on how to start the first of the preprogrammed scenarios that were analyzed. After the researcher received verbal confirmation of understanding from the participant, he/she completed the scenarios as assigned. The PI observed the scenario(s) and completed the *P-Drive* simultaneously.

For within-subject repeated measures design participants, included to establish a baseline, measurement 2 was administered in the same manner as Time 1 after a three week control period. Brief instruction or reminders were provided to the participants regarding the simulator and after the participant verbally confirmed understanding the practice drive was completed again. Following the practice drive, the two randomly assigned simulator scenarios were completed while the researcher completed the *P-Drive*. This process was the same for Time 3 of within-subject participants and Time 1 and 2 for pre- and post-test participants.

All *P-Drive* assessments were scored by two to three raters with a minimum of one rater blind to the drive conditions. The raters included the PI and two individuals experienced with the driving simulator and trained in completion of the *P-Drive*. The PI randomly assigned the order in which other researchers would review the scenario recordings and played them accordingly to ensure other raters were blind to driving condition. Excellent inter-rater reliability was found (α = .953) across all *P-Drive* scores.

The intervention was completed virtually or in the same location as the initial meeting for approximately 30-60 minutes, as described below.

Intervention

Drive Focus® (Monahan et al., 2020) was provided for all participants' individual use throughout participation in this study. This interactive application contains real footage of drives throughout North America in which each participant must identify all critical items on the touch screen. These 11 critical items include stop signs, traffic lights, yield signs, brake lights, turn signals, pedestrians and bicyclists, regulatory signs, caution signs, pavement markings, vehicles entering from the left or right, construction signs, and objects in the driver's path (see Appendix F). In addition to touching all critical items, the items must be touched in the correct order of prioritization based on immediacy of reaction. For example, when approaching an intersection with a green light and a stopped car with its brake lights on in front of you (both critical items), the brake lights should be prioritized because the driver may need to react by slowing down or stopping before ever reaching the green light. A scored is provided at the conclusion of each drive that depicts how many critical items were identified, how quickly, and if correct prioritization was achieved (see Appendix G).

The intervention protocol was determined based on both the pilot efficacy study conducted by Alvarez et al. (2018) and the instructions of use within the app. In the Alvarez et al. (2020) pilot study, participants completed six, 45-minute intervention sessions over a 9-week period. In order to maintain participant engagement and avoid dropout from the present study, participants completed the six 45-minute intervention sessions over a 6-week period. All participants were required to receive a score of 500 or more on all drives to continue based on the app's design. During all intervention sessions the primary researcher was either with the participant or present through virtual means.

The first session utilized the in-app training section and practice drives to orient participants to use of the app. The general training tab was reviewed followed by the first three critical items (i.e. stop signs, traffic lights, and yield signs). After this training, *practice drive 1* was completed since it focused on these hazards. Critical items four to six (i.e., regulatory signs, pedestrians and bicyclists, and brake lights and turn signals) were reviewed next and *practice drive 2* was completed. *Practice drive 3* included critical items seven to nine (i.e., pavement markings, vehicles entering driver's path, and warning signs). Finally, critical items ten and eleven (i.e., construction signs and objects in road) were completed. The next step was to review the *Prioritization* training page and then *practice drive 4* was completed. This design of session one oriented participants to the use of *Drive Focus*®, ensured their understanding of critical items moving forward, and was completed in the same order for each of the participants.

In the other five (of six) intervention sessions participants completed one tour per session independently under the PI's observation, assisting as necessary. A tour is a set of six or seven drives recorded in the same geographic location. The drives in each tour are ordered in increasing complexity with more difficult drives having more critical items. In this study, participants completed the Southern California, South Carolina, Vermont, Florida, and Ontario in the order he/she desired. After each drive was completed, *Drive Focus*® visually displays the participants' scores for the drive including percentage of critical items noticed, percentage of time items were noticed in correct sequence, and reaction time (see Appendix G).

Data Analysis

Descriptive statistics were used to describe participant demographics including gender, age, and driving experience. Additionally, descriptive statistics were utilized to describe AASP outcomes. The outcome measures for the three within subjects repeated measures participants were analyzed using Wilcoxon Signed Rank Test for *P-Drive* outcomes and repeated measures ANOVA for eye tracking data. For the remainder of participants in the pre- and post- condition, outcome measures of *P-Drive* and eye tracking data were analyzed using paired t-tests and repeated measures ANOVAs respectively to determine whether or not significant differences in pre- and post-test scores were present. The significance level for statistical testing was set at 0.05 and significant differences in these outcome measures determined whether or not the visual support intervention, *Drive Focus®,* is effective in improving hazard perception and driving performance of autistic individuals.

Specifically, the research questions are:

1. Is there a significant difference between the pre- and post- overall driving performance scores as measured by the *P-Drive*?
    a. In addition, each category (e.g., *maneuver*, *orient*, *follow regulations*, *heeding*) will also be examined.
2. Is there a significant difference between pre- and post- time a person spends looking at a hazard (i.e., *fixation duration*), how many times a person looks at a specific hazard (i.e., *fixation count*), and how long it takes to look at a hazard once it is visible (i.e., *time to first fixation*)?
3. Is there a significant difference in number of critical and non-critical hazards recognized from pre- to post-measurements?

Chapter 4: Results

Demographics

Participant demographics were obtained and are described in Table 3. It is beneficial to note the largest group of participants (9) had no driving experience while three had received their learner's permit and two had driver's licenses.

Table 3

Participant Demographics

N	Age M (SD)	Males/Females	Driving Experience Level		
			None	Learner's Permit	Driver's License
14	19.0 (4.33)	10/4	9	3	2

Sensory Processing

Table 4 shows the distribution of the *Adolescent/Adult Sensory Profile (AASP)* results. To analyze participants' individual *AASP* scores see Appendix H. In general, participants scored within the "similar to most people" percentile most frequently for low registration (n = 8) and sensory sensitivity (n = 10). However, participants most commonly scored in the "less than most people" percentile for sensation seeking and equally between "more than most people" (n = 5) and "much more than most people" (n = 5) percentiles for sensation avoiding.

These results were analyzed in terms of their impact on *P-Drive* scores with repeated measures ANOVAs. Sex, age, and driving experience were included as between-subject factors with no significant effect of these factors. This analysis revealed that variance in *sensation seeking* had a significant impact as a between-subjects variable on the *orientate* category scores of the *P-Drive* ($F(4, 21) = 3.640$, $p = .021$). All other sensory findings were not statistically significant.

Table 4

Adolescent/Adult Sensory Profile (AASP) Results (N=14)

Score Category	Low Registration	Sensation Seeking	Sensory Sensitivity	Sensation Avoiding
Much Less Than Most People	0	1	0	0
Less Than Most People	0	6	0	0
Similar To Most People	8	5	10	4
More Than Most People	4	1	1	5
Much More Than Most People	2	1	3	5

Within Subject Baseline

Comparing the baseline results (Time 1) to Time 2 with no intervention between measurements for three participants was important to show that practice effects on the simulator are controlled and assist in ruling out other potential factors on driving performance. Assuming there would be no difference without the intervention would strengthen any changes after the intervention.

In terms of eye tracking there was no difference for any of the three within subjects repeated measures design participants between Time 1 and Time 2. Analysis was completed after three participants completed the study with repeated measures ANOVA after transforming the data to achieve normal distribution. *Time to first fixation* revealed no significant change with $F(1, 4) = 4.212$, p = .109 for the *rural* scenario and $F(1, 3) = .621$, p = .488 for the *urban* scenario. The *number of fixations* data was transformed by Log10+1 transformation with no difference in the *rural* scenario ($F(1, 7) = 2.280$, p = .175) or *urban* scenario ($F(1, 8) = .321$, p = .587). The *average duration of fixation* statistical analysis showed similar results for *urban* scenario $F(1, 8) = 3.482$, p = .099 and *rural* scenario, $F(1, 7) = 1.893$, p = .211. Each of these analyses were conducted with sex, age, and driving experience as between-subject factors but there was no significant effect of these factors found.

Due to the small number of participants in this category, the *P-Drive* scores for these participants were not normally distributed, even with log transformation, and therefore were analyzed using a Wilcoxon Signed Rank Test. This test showed no significant difference for the total *P-Drive* scores ($Z = 4.00$, $p = .564$). It also showed no significance difference for the post-test in categories *maneuvers* ($Z = 4.00$, $p = .564$) *follows regulations* ($Z = 1.00$, $p = .317$), *orientate* ($Z = 4.50$, $p = .414$), and *heeding* ($Z = 1.50$, $p = 1.00$).

These results show there was no significant difference between the two pre- intervention measurements for the three within subjects repeated design participants. Based on these results, the extra baseline data was not considered necessary for the other participants.

Effect of Intervention

Change in Driving Performance

Table 5 shows all *P-Drive* repeated measure ANOVAs with sex, age, and driving experience as between-subject variables. The increase in mean scores was most notable in the overall *urban* scenario (*pre:* $M_U = 66.31$, $SD = 7.95$; *post:* $M_U = 69.85$, $SD = 10.00$). Overall scores (i.e. all four categories combined) and the categories of *follow regulations* and *heeding* were not significantly different for either of the driving scenarios (i.e., *rural* and *urban*). The category *maneuvers* was not significant in *rural* scenario while there was a significant difference in *maneuvers* from pre- to post- in *urban* scenario (F(1, 12) = 6.945, p = .022). Conversely, the category *orientate* was not significant in *urban* scenario and was significant in *rural* scenario (F(1, 12) = 6.720, p = .024). Other factors including age, sex, and driving experience did not significantly influence results.

Table 5

Driving Performance: Paired T-test Comparing P-Drive Scores Pre and Post

Score Category	Time	M(SD)	Min.	Max.	Median	F(df1, df2)	P-Value
Overall P-Drive Score (Out of 88)	**Rural**						
	Pre	69.14(8.574)	58	83	68	.026(1, 12)	.874
	Post	69.86(9.631)	54	84	67		
	Urban						
	Pre	66.31(7.952)	46	77	68	1.551(1, 12)	.237
	Post	69.85(9.999)	51	85	74		
Maneuvers (Out of 20)	**Rural**						
	Pre	17.43(1.950)	14	20	18	4.333(1, 12)	.059
	Post	16.79(2.914)	10	20	17		
	Urban						
	Pre	16.46(2.436)	11	20	17	6.945(1, 12)	**.022**
	Post	18.23(2.006)	15	20	18		
Orientate (Out of 16)	**Rural**						
	Pre	11.71(1.978)	8	15	11	6.720(1, 12)	**.024**
	Post	12.86(1.994)	9	16	12		
	Urban						
	Pre	12.31(2.626)	8	16	13	.242(1, 12)	.632
	Post	12.77(2.048)	8	15	13		
Follows Regulations (Out of 12)	**Rural**						
	Pre	11.36(1.151)	9	12	12	.920(1, 12)	.356
	Post	11.00(1.414)	9	12	12		
	Urban						
	Pre	11.31(1.182)	9	12	12	.021(1, 12)	.888
	Post	11.23(1.481)	7	12	12		
Heeding (Out of 40)	**Rural**						
	Pre	28.64(5.597)	20	39	27	.128(1, 12)	.726
	Post	29.21(5.250)	20	37	31		
	Urban						
	Pre	26.77(4.343)	18	37	27	1.408(1, 12)	.258
	Post	28.38(5.738)	20	39	28		
Note: p<0.05							

Change in Visual Attention

Eye tracking data (*time to first fixation, number of fixations, and average duration of fixation)* was analyzed using repeated measure ANOVAs to determine significant differences in visual attention while driving. Additionally, this statistic allowed researchers to analyze the impact of between-subject factors including sex, age, and driving experience. These factors were included in each analysis but None of these variables significantly impacted visual attention results. Since some participants did not “gaze” at some of the critical events in the scenarios or due to missed fixations of the eye tracking software, there is missing data in the analyses.

Time to First Fixation. Time to first fixation data was transformed using a log10+2 transformation to obtain normal distribution. Differences in time to first fixation for the rural scenario can be seen in Table 6 and the urban scenario in Table 7. For both the rural, $F(1, 63) = .167$, $p = .684$), and urban scenario, $F(1, 47) = .305$, $p = .583$, there were no significant difference of *time to first fixation* overall (i.e., all hazards combined). Additionally, there were no significant differences for any of the individual hazard types from the pre- to post-measurements. However, there was a positive trend in *time to first fixation* toward *pedestrians* in the *urban* scenario.

For the *rural* scenario, participants detected 78.85% (41 out of 52) of non-critical hazards in the pre-test while in post-test, 82.69% (43 out of 52) of non-critical hazards were detected. As expected, more critical items were detected in the *rural* pre-test (90%; 36 out of 40). However, only 82.5% (33 out of 40) of critical items were detected in the post-test. The *urban* scenario was similar with 76.92% (10 out of 13) of non-critical items detected in pre-test and 69.23% (9 out of 13) in post-test. In terms of critical items, 88.68% (47 out of 53) of critical items were detected in pre-test and 86.79% (46 out of 53) were detected in post-test.

Table 6

Time to First Fixation on the Rural Scenario for Specific Individual Hazards

Time to First Fixation (sec.)				
Hazard	**Pre M(SD)**	**Post M(SD)**	**F(df1, df2)**	**P-Value**
Critical Items				
Head on Collision	2.000(.2535)	2.0578(.2387)	.220 (1, 9)	.650
Object in Road 1	1.991(.2067)	1.955(.2280)	.158 (1, 7)	.703
Object in Road 2	2.181(.4458)	2.145(.4917)	.081 (1, 10)	.782
Non-Critical Items				
Object on Shoulder 1	1.965(.5103)	1.908(.4577)	.060 (1, 9)	.812
Object on Shoulder 2	2.022(.3035)	1.906(.2248)	1.195 (1, 9)	.303
Object on Shoulder 3	1.863(.3791)	1.921(.4090)	.078 (1, 7)	.789
Oncoming Traffic	2.692(.5945)	2.658(.6734)	.014 (1, 6)	.911
Note: All data transformed with Log10+2; p<0.05				

Table 7

Time to First Fixation on the Urban Scenario for Specific Individual Hazards

Hazard	**Pre M(SD)**	**Post M(SD)**	**F(df1, df2)**	**P-Value**
Critical Cues				
Pedestrians	2.353(.2687)	2.126(.2653)	4.700 (1, 12)	.051*
Traffic Lights/Stop Signs	2.080(.5779)	2.236(.5263)	.124 (1, 12)	.739
Object in Road	2.205(.2980)	2.155(.4679)	.059 (1, 7)	.815
Traffic	2.561(.4197)	2.529(.5659)	.028 (1, 12)	.869
Non-Critical Items				
Oncoming Traffic	2.115(.4752)	2.165(.6006)	.052 (1, 7)	.826
Note: All data transformed with Log10+2; p<0.05				

Number of Fixations. *Number of fixations* data was transformed using the Log10+1 formation to achieve normal distribution and ensure all data was greater than zero. Overall (i.e., hazards combined) scores show there was no significant difference in the number of fixations at critical and non-critical items for either *rural* ($F(1, 92) = .055$, $p = .815$) or *urban* scenarios ($F(1, 110) = .511$, $p = .476$). In addition to the overall scores, analyses were done for each specific hazard (see Table 8 for the *rural* scenario and Table 9 for the *urban* scenario). There were no significant differences, although in the *urban* scenario, there was a positive trend in the *number of fixations* on the *mirror*, as a critical cue.

Table 8

Number of Fixations on the Rural Scenario for Specific Individual Hazards

Hazard	Pre M(SD)	Post M(SD)	F(df1, df2)	P-Value
Critical Items				
Head-on Collision	1.631(.2006)	1.603(.3660)	.036 (1, 9)	.854
Object/Hazard in Road	2.429(.6721)	2.257(.5547)	.451 (1, 12)	.515
Non-Critical Items				
Dynamic Object	2.122(.3892)	2.134(.4317)	.005 (1, 11)	.947
Oncoming/ Passing Traffic	1.966(.6368)	2.291(.6259)	.919 (1, 10)	.360
Critical Cues				
Mirrors	2.604(.3645)	2.554(.4527)	.188 (1, 11)	.673
Other Signs	2.313(.3680)	2.262(.3206)	.084 (1, 10)	.778
Speed Limit Signs	1.877(.4017)	1.797(.4095)	.146 (1, 11)	.710
Speedometer	3.149(.1930)	3.094(.3422)	.242 (1, 11)	.633
Note: All data transformed with Log10+1; $p<0.05$				

Table 9

Number of Fixations on the Urban Scenario for Specific Individual Hazards

Hazard	Pre M(SD)	Post M(SD)	F(df1, df2)	P-Value
Critical Items				
Merging/Pulling Out Traffic	2.191(.5285)	2.342(.3603)	.613 (1, 12)	.449
Object/Hazard in Road	1.822(.4495)	1.725(.5396)	.148 (1, 9)	.709
Slow Traffic/ Parked Cars	2.479(.62046)	2.340(.5387)	.317 (1, 12)	.584
Pedestrian Crossing	2.113(.4302)	2.210(.4806)	1.463 (1, 11)	.252
Stop Signs/ Traffic Lights	2.295(.2272)	2.365(.2919)	.311 (1, 10)	.590
Non-Critical Items				
Merging/Pulling Out Traffic	1.826(.6219)	1.722(.3135)	.098 (1, 3)	.774
Oncoming/ Passing Traffic	1.490(.5445)	1.783(.6588)	.673 (1, 8)	.436
Pedestrian	2.534(.2560)	2.637(.2792)	1.297 (1, 11)	.279
Critical Cues				
Mirrors	2.687(.3723)	2.469(.3809)	4.567 (1, 11)	.056*
Speed Limit Signs	1.844(.3854)	2.007(.2832)	1.153 (1, 11)	.306
Speedometer	2.846(.3410)	2.931(.4100)	.517 (1, 12)	.486
Note: All data transformed with Log10+1; $p<0.05$				

Average Fixation Duration. *Average fixation duration* data was transformed using the Log10+2 transformation to obtain normal distribution. There was no difference in overall *average duration fixation* between pre-test and post-test for the *urban* scenario ($F(1, 110) = .642$, $p = .425$). However, there was a significant difference found between pre- and post-test on the *rural* scenario in terms of *average fixation duration* ($F(1, 92) = .208$, $p = .007$). Table 10 and 11 analyses were done for each specific hazard (see Table 10 for the *rural* scenario and Table 11 for *urban* scenario).

Interestingly, for the *rural* scenario, *Other Signs* was significantly different, suggesting participants spent, on average, more time to looking at signs (e.g., intersection or sharp curve warning signs) other than speed limit signs, $F(1, 10)= 8.139$, $p = .017$. In contrast, for the *urban* scenario, participants increased their *average duration of fixation* on *Pedestrians* ($F(1, 11)= 5.035$, $p = .046$). While not significant, several other "hazards" were found to have a positive trend, specifically *mirrors* and *speedometer* in the *rural* scenario and *objects on the road* in the *urban* scenario.

Table 10

Average Duration of Fixations on the Rural Scenario for Specific Individual Hazards

Hazard	Pre M(SD)	Post M(SD)	F(df1, df2)	P-Value
Critical Items				
Head-on Collision	1.765(.3533)	1.852(.3560)	.668 (1, 9)	.435
Object/Hazard in Road	1.528(.2982)	1.629(.2612)	2.215 (1, 12)	.163
Non-Critical Items				
Dynamic Object	1.616(.2382)	1.621(.1869)	.007 (1, 11)	.937
Oncoming /Passing Traffic	1.597(.2812)	1.652(.2011)	.365 (1, 10)	.559
Critical Cues				
Mirrors	1.303(.1282)	1.374(.1020)	3.719 (1, 11)	.080*
Other Signs	1.526(.3061)	1.674(.2062)	8.139 (1, 10)	**.017**
Speed Limit Signs	1.634(.3039)	1.662(.3930)	.081 (1, 11)	.781
Speedometer	1.499(.2206)	1.546(.2173)	3.239 (1, 11)	.099*
Note: All data transformed with Log10+2; p<0.05				

Table 11

Average Duration of Fixations on the Urban Scenario for Specific Individual Hazards

Hazard	Pre M(SD)	Post M(SD)	F(df1, df2)	P-Value
Critical Items				
Merging/Pulling Out Traffic	1.453(.2745)	1.416(.2212)	.454 (1, 12)	.513
Object/Hazard in Road	1.666(.3207)	1.461(.2662)	3.977 (1, 9)	.080*
Slow Traffic/ Parked Cars	1.535(.3046)	1.569(.3168)	.311 (1, 12)	.587
Pedestrian Crossing	1.520(.2805)	1.548(.2203)	.182 (1, 11)	.678
Stop Signs/ Traffic Lights	1.492(.2213)	1.496(.2843)	.002 (1, 10)	.962
Non-Critical Items				
Merging/Pulling Out Traffic	1.435(.1537)	1.489(.3445)	.068 (1, 4)	.808
Oncoming/ Passing Traffic	1.274(.2298)	1.327(.1868)	.265 (1, 9)	.619
Pedestrian	1.385(.1184)	1.461(.1244)	5.035 (1, 11)	**.046**
Critical Cues				
Mirrors	1.308(.1383)	1.261(.1241)	.659 (1, 11)	.434
Speed Limit Signs	1.446(.1777)	1.517(.2033)	.811 (1, 11)	.387
Speedometer	1.430(.2198)	1.455(.21317	.332 (1, 12)	.575
Note: All data transformed with Log10+2; p<0.05				

Chapter 5: Discussion

The objective of this study was to explore if and how using visual supports as an occupational therapy intervention will improve driving performance in individuals with ASD. Specifically, the app *Drive Focus®* was used as the intervention for learning to identify and prioritize critical hazards with the participants' performance on an interactive driving simulator as the outcome measure to determine the effectiveness of the intervention. In addition to using a standardized observational tool, eye tracking technology offered the ability to measure if an individual visually attended to critical and non-critical hazards and/or cues. There was no significant difference in the number of critical or non-critical items visually observed between pre- and post-test scenarios. However, there were several significant differences found in both driving performance measured through observation (*P-Drive)* and certain visual attention measures quantified by eye tracking technology.

Overall, these results align with previous literature about both Drive Focus® and visual supports. All research on the preliminary efficacy of *Drive Focus®* suggested the intervention may improve driving performance (Alvarez et al., 2018, 2019). Previous literature regarding visual supports suggests these interventions may improve autistic individual's ability to focus, allocate attention appropriately, and improve movement deficits (Pierce & Schreibman, 1994; Rutherford et al., 2020). Further research suggested visual supports that utilize video technology may be more effective in improving IADL performance (Van Laarhoven et al., 2010). To consider these results most effectively driving performance and eye tracking data must be considered together as well as in conjunction with other participant factors.

Sensory Processing

In terms of sensory processing, most of the participants (10 of the 14) self-reported that they do not have a sensitivity to sensory stimuli (*sensory sensitivity)* and register information at a level similar to neurotypical peers (*low registration*; 8 of the 14). However, the largest category reported by participants for *sensation seeking* indicated they do not typically seek sensory input (6 of the 14). In fact, 10 of the 14 participants reported that they tend to avoid sensory stimuli when given the option (*sensation avoiding*).

This aligns with findings from previous literature that autistic individuals tend to avoid looking at objects that produce more sensory stimulation and focus on background textures of their environment (Wang et al., 2015). When analyzed, sensory processing did not have a significant effect on driving performance with one exception. *Sensation seeking* in the orientate category showed a significant difference in driving performance. If individuals sought sensation less frequently, their *orientate* scores were lower than those who more frequently seek out sensation. In the context of driving this may mean those participants who avoid sensory stimuli may not like to look around at busy intersections or may tend to look at less crowded areas of the driving environment. This could lead to avoiding looking at hazards or missing them all together which would then decrease *orientate* driving skills of positioning on the road, keeping distance from others, following directions, and planning. Since ASD exists on a spectrum, this finding provides meaningful insight into those who may be most appropriate to receive this, and other, visual support interventions.

Performance Results

Changes in visual attention were measured by eye tracking using several ways to measure eye motions. In this study, the overall *number of fixations* for critical and non-critical items and *time to first fixation* in both *rural* and *urban* scenarios were not found to be significantly different from pre- to post-test. This finding was slightly surprising given previous literature that reports autistic individuals' slower time to first fixation (Sheppard et al., 2017). However, the small sample size and short intervention timeframe in this study may mean further research on the effectiveness of visual support interventions to address *time to first fixation* is needed. Although these outcomes did not show significant change, there was a notable outcome with the *average duration of fixation.* This outcome can be difficult to analyze meaningfully because increased average duration of fixation could mean participants spent too long looking at a specific hazard, resulting in decreased driving performance. On the other hand, drivers may demonstrate more appropriate duration of fixation that results in improvements in driving performance.

From the observational perspective with *P-Drive*, there was no change in the overall driving performance as a result of the intervention in *rural* or *urban* scenarios. While this would suggest the intervention was not effective, examining the categories of the *P-Drive* offers more specific information about potential change in certain abilities or skills of driving. Specifically, there were significant changes in the categories *maneuvers* in the *urban* scenario and *orientate* in the *rural* scenario as well as other results that differed between *rural* and *urban* scenarios which will be discussed.

Rural Scenario

When driving the *rural* scenario, participants showed significantly improved performance in the *orientate P-Drive* category. The *orientate* category has four scoreable items for a simulator including tactical skills (e.g. positioning on the road, keeping distance from other cars) and strategic level skills (e.g. following instructions, planning). To improve in performance, the driver needed to be more aware of the environment to respond quickly and appropriately, keep their vehicle within the correct lane, and avoid hazards. This positive finding of change was also supported by the eye tracking findings. With the *rural* scenario, there was a statistically significant increase in overall *average duration of fixation* of critical hazards and/or cues and an increase in *average fixation of duration* toward *signs*. Both results suggest the intervention improved participants' hazard detection and prioritization of important signage within the driving environment. In addition, there was an increase in *average duration of fixation* toward *mirrors* and the *speedometer*, although these findings were only trends in the data.

In consideration of these results, this suggests post-intervention participants spent more time processing hazards and critical cues while driving in the *rural* environment. In combination with the increase in *orientate* scores for this scenario, the increased *average duration of fixation* suggests an improvement in visual attention and hazard detection. The increase in *orientate* scores suggests drivers are more appropriately positioning their vehicle on the road, keeping distance from other vehicles, following instructions, and planning. If the driver spends a more effective amount of time processing hazards and critical cues it is more likely they will make more appropriate decisions in terms of those items. Thus orienting the vehicle to the driving environment and planning accordingly becomes much more likely. Additionally, *average duration of fixation* toward *mirrors* and the *speedometer* were improved, having a similar positive effect on one's ability to orient the vehicle within the environment and plan accordingly. Moreover, attention allocation was defined as one of the most significant deficits in the autistic population while driving (Reimer et al., 2013; Underwood, 2007, Wang et al., 2015).

In terms of number of identified hazards classified as critical (e.g., pedestrians crossing, objects in the road, head-on collisions) and non-critical (e.g., object on shoulder, pedestrians on sidewalk), there was no significant difference between before and after the intervention. This is not surprising given previous findings that appropriate duration and speed of attention allocation is a deficit in this population rather than identifying hazards (Sheppard et al., 2017). However, participants did increase the number of critical items identified and decrease the number of non-critical items identified from pre- to post- measurements. This supports improved performance as suggested by driving performance and visual attention data for this scenario as participants spent more time looking at signs and other cues that improved their orientation while driving.

Potentially, the low number of participants is the reason for fewer statistically significant changes. Nevertheless, these combined results support the idea that post-intervention participants were giving more visual attention to hazards and suggests the intervention was effective. The intervention facilitated improved processing of information and therefore improved driving performance especially in the *orientate* category, at least for *rural* scenario.

Urban Scenario

In the *urban* scenario participants showed significantly improved performance in the *P-Drive* category *maneuvers*. This includes five scoreable items on a driving simulator related primarily to the operational level of driving skills (e.g., steering, using pedals, controlling speed fast and slow, and using an indicator), a known driving deficit for autistic individuals (Chee et al., 2017). To improve in these scores participants needed to identify hazards more quickly and allot increased visual processing toward hazards that present the need for a difficult driving maneuver. For example, when a pedestrian walks across the street abruptly drivers were required to maneuver the vehicle more skillfully (i.e. abruptly push brakes, steer away from object) when compared to typical driving conditions. This finding is supported by previous literature that suggested visual supports may improve individual's motor coordination (Breslin & Rudisill, 2011). Moreover, it is supported by eye tracking findings for this scenario. There was a statistically significant difference in *average duration of fixation* toward *pedestrians* and an positive trend in *average fixation of duration* toward *objects in road*. These results suggest that the intervention improved critical hazard detection and prioritization of *pedestrians.*

This result has important implications given the currently mixed research regarding differences of autistic individual's ability to recognize social hazards compared to typically developing populations (Sheppard et al., 2010, 2017; Guillon et al., 2010). *Pedestrians* were the only social hazard offered in this study and the only statistically significant finding in the *urban* driving environment. This again suggests the visual support intervention, Drive Focus®, appropriately targeted specific deficits and improvement in visual attention toward hazards.

Overall, this increased effectiveness of visual attention toward *pedestrians* and potentially other critical items (i.e., *objects in road)* while driving gave participants increased processing time to potentially improve decision making about how to operationally drive the vehicle. These results suggest the effectiveness of the intervention for the *urban* scenario as well as the *rural*, although in different ways.

Differences Between the Two Scenario Types

These results raise the question of why there were different outcomes in the two types of scenarios. It is known that different hazards are present in different driving environments. This, different driving skills are needed in different environments. The differences in *average duration of fixation* between *rural* and *urban* scenarios are likely due to the overall different nature between the two. In the *rural* scenario, critical pedestrians were not analyzed as a hazard as they were not present. Similarly, *signs* were not as prevalent in the *urban* scenario. Thus statistical analysis of these hazards yielded different results based on type of driving scenario.

The overall difference in *average duration of fixation* being present in the *rural* scenario and not in the *urban* scenario is likely due to the difference in the pace or speed of driving. The *urban* scenario was much faster paced than the *rural* scenario and encompassed a much more complex or "busier" environment. This highly paced scenario likely did not lend to spending significantly more time looking at the majority of urban hazards, especially critical cues such as signs or other less critical hazards.

Similarly, no change in *orientate* scores was found in the *urban* scenario may be because visual attention was directed at different objects. In the *rural* scenario, objects such as other signs were given more visual attention while the *urban* scenario demonstrated an increase in visual attention toward critical hazards such as *pedestrians*, which are not seen in the *rural* scenario. In other words, depending on the type of scenario, the improvement was related to the driving environment (i.e., *rural* or *urban*). Improved ability to process critical hazards, non-critical hazards, and critical cues increases processing time to react appropriately. In the *rural* scenario increased visual attention to *signs, mirrors,* and the *speedometer* lend themselves to improved positioning on the road, following instructions, and planning (i.e., *orientate* skills). In the *urban* scenario, attention was needed to unexpected hazards (i.e., pedestrians, objects in the road). Improvement was much less about planning or positioning in the road, but on the actions needed to avoid hazards, thus, the change in the category of *maneuvers* (i.e., skills such as steering and using pedals) to avoid hazards.

This difference found in terms of *maneuvers* skills in the *urban* scenario additionally introduces the question of learning occurring between the pre- and post- test as *maneuvers* encompasses many skills needed to operate the driving simulator. Moreover, these operational skills are those that require the focus of novice drivers but become automatically performed without conscious thought as driving experience increases. Due to the majority of participants being novice drivers, these results are not surprising. Additionally, previous literature regarding the effectiveness of *Drive Focus®* suggested that while all drivers may benefit from the intervention, novice drivers may demonstrate a more significant benefit than experienced drivers (Alvarez et al., 2019). However, this improvement was not found to be statistically significant in the *rural* scenario suggesting changes are not due to learning alone. More likely these findings could be due to overall increase in driving environment awareness seen through eye tracking data and a result of the intervention.

Limitations

One of the biggest limitations to this study is the difficulty of recruiting from the population of interest, particularly during the COVID-19 pandemic. To control for both this limitation participants were monetarily compensated for their participation in increments at each measurement time. No participants dropped out of the experiment early. However, it is important to note that this study was underpowered and it is possible that findings would be present in all types of driving conditions. However, future research is needed to make this claim.

Another limitation is presented when considering the technology utilized. The *Tobii Pro Glasses 3* are a piece of technology and therefore some glances were missed in data collection due participants' pupil size and lighting while recording. Additionally, all eye tracking data required coding and analysis individually. To address this limitation, researchers ensured lighting was identical throughout participants' time on the driving simulator to maximize eye tracking effectiveness. Additionally, only one driving scenario was found to have below 80% visual tracking accuracy per the *Tobii pro* analysis software.

Implications for Practice

Based on the results of this study, visual supports such as *Drive Focus®* may be used as an effective occupational therapy intervention to improve driving performance in the autistic population by learning to identify hazards and prioritize their importance. Visual supports may be used to address both driving performance and visual attention deficits while driving.

To effectively use this intervention a comprehensive evaluation should be completed in which a sensory assessment and initial driving performance is evaluated. Based on results, therapists should use clinical judgement to determine whether or not clients would benefit from improvements in *maneuvers* skills, *orientate* skills, or increases in *average duration of fixation*. This visual support intervention may be of particular effectiveness if deficits in visually processing *signs* in *rural* environments or *pedestrians* in *urban* environments are present. However, more research is required for the use of *Drive Focus*® as an intervention to improve hazard detection of other hazards (i.e., not *signs* and *pedestrians*). Additionally, client's driving environment should be considered to target the appropriate type of hazards in rural (i.e., critical cues) and urban (i.e., critical hazards) environments.

The use of this intervention may vary based on sensory information obtained during evaluation. For clients with evidence of *sensation seeking*, therapists can capitalize on client's strengths in following instructions, positioning on the road, keeping distance from other road users, and planning (i.e., *orientate* skills). In this case, the intervention should focus on *maneuvers, follow regulations, and heeding* skills. Similarly, those who do not seek sensation (i.e. *sensation avoiding*) or have a sensitivity to sensory input (i.e., *sensory sensitivity*) may have decreased *orientate* skills although further research is needed to confirm this correlation.

Overall, occupational therapists may use visual support interventions to address deficits in IADL performance for the autistic population. However, each visual support may provide different benefits to clients. Therapists should be selective when choosing a visual support intervention that is best for their client(s). Specifically, visual support interventions like *Drive Focus®* that are accessible, participation-focused, individualized, consistent, and include pertinent information with teaching methods may lead to more significant driving and IADL performance (Rutherford et al., 2020).

Chapter 6: Conclusion

The literature confirms autistic individuals face barriers in obtaining a driver's license due to motor, sensory, cognitive, and visual attention differences. Research has shown visual supports are an effective and widely used intervention for autistic individuals across the lifespan. However, prior to this study there was no research of the effectiveness of visual supports on driving performance for autistic individuals. Moreover, while there has been research on *Drive Focus*® as an app, it has not been previously identified as a type of visual support for improving driving ability. Overall, findings in this study support the effectiveness of visual supports, such as Drive Focus®, as an intervention for visual attention and ultimately driving performance.

The positive influence this visual support had varied based on driving condition (i.e., *urban* and *rural*). However, regardless of condition, the intervention may have given participants the ability to allot more visual attention to critical items as it pertained to the driving environment. This increased processing of these items and therefore increased driving performance accordingly. However, due to the small sample size further research needs to be completed to help determine the efficacy of using visual supports to improve driving performance in this population.

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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 Initial Approval: Expedited

From: Biomedical IRB
To: Haley Poythress
CC: Anne Dickerson
Date: 6/22/2021
Re: UMCIRB 21-000792
Visual Supports for Driving

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 6/21/2021. The research study is eligible for review under expedited category # 4. 6 7. 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 UMICRB 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.

The approval includes the following items:

Name	Description
Adult Consent	Consent Forms
Adult/Adolescent Sensory Profile	Surveys and Questionnaires
Assent	Consent Forms
Demographic Questionnaire	Surveys and Questionnaires
Demographic Questionnaire.docx	Data Collection Sheet
Effect of Visual Supports on Driving Performance for Individuals with ASD Proposal.docx	Study Protocol or Grant Application
Email Recruitment Flyer	Recruitment Documents/Scripts
Parent Consent	Consent Forms

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.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

Appendix B

Demographic Questionnaire

1. Name ____
2. Age ____
3. Sex ☐ Male ☐ Female ☐ Other ☐ Prefer not to answer
4. Have you been diagnosed with Autism Spectrum Disorder? ☐ Yes ☐ No
5. Have you been diagnosed with anything in addition to ASD? ☐ Yes ☐ No
6. If yes, what other diagnosis do you have?

____

7. Have your received rules of the road driving instruction? ☐ Yes ☐ No
8. Do you have a valid driver's license? ☐ Yes ☐ No
9. If yes, when did you get your driver's license? ___________________________________
10. What was the last grade in school you completed?________________________________
11. Do you have any diagnosed motion sickness, vertigo, vestibular, or hearing disorders?

    ☐ Yes ☐ No
12. Do you wear glasses or contacts when you drive? ☐ Yes ☐ No

Appendix C

P-Drive Scoring Sheet

P -Drive

Performance Analysis of Driving Ability

Name (not to be written for research)		Rater	
Id.no.	Age	Date for assessment	
Diagnosis		Date of onset	Time since diagnosis (months)
Cognitive tests done		Advised not to drive (y/n)	Driving anyway (y/n)

☐ **Manual** ☐ **Automatic** ☐ **Modification/s**___________

Actions (1-26):

Maneuvers

1. steering	4	3	2	1
2. changing gears	4	3	2	1
3. using pedals	4	3	2	1
4. contr speed, slow	4	3	2	1
5. contr speed, fast	4	3	2	1
6. using indicator	4	3	2	1
7. reversing	4	3	2	1

Orientate

8. following instruct	4	3	2	1
9. finding the way	4	3	2	1
10. positioning on road	4	3	2	1
11. keeping distance	4	3	2	1
12. planning	4	3	2	1

Follow regulations

13. Yielding	4	3	2	1
14. obeying stop	4	3	2	1
15. follow speed reg	4	3	2	1

Attending and acting (heeding)

16. straight ahead	4	3	2	1
17. to the right	4	3	2	1
18. to the left	4	3	2	1
19. to mirrors	4	3	2	1
20. to regulatory sign	4	3	2	1
21. to advisory sign	4	3	2	1
22. to fellow road users	4	3	2	1
23. reacting	4	3	2	1
24. focusing	4	3	2	1
25. problem solving	4	3	2	1

Rating scale	**Quality of performance**	**Impact on the activity**
4	Good **Competent performance**	Positive, facilitating
3	Questionable **Hesitant performance**	Causing insecurity (asking questions)
2	**Ineffective Performance**	Causing risky situation
1	**Incompetent performance**	Causing repeated risky or dangerous situations. Interruption

Other information:

Standard route ☐ Special route ☐

Signed consent form ☐

Time on-road (min):_________

OUTCOME: ☐ Pass ☐ Fail

☐ Fail with lessons

☐ Other____________

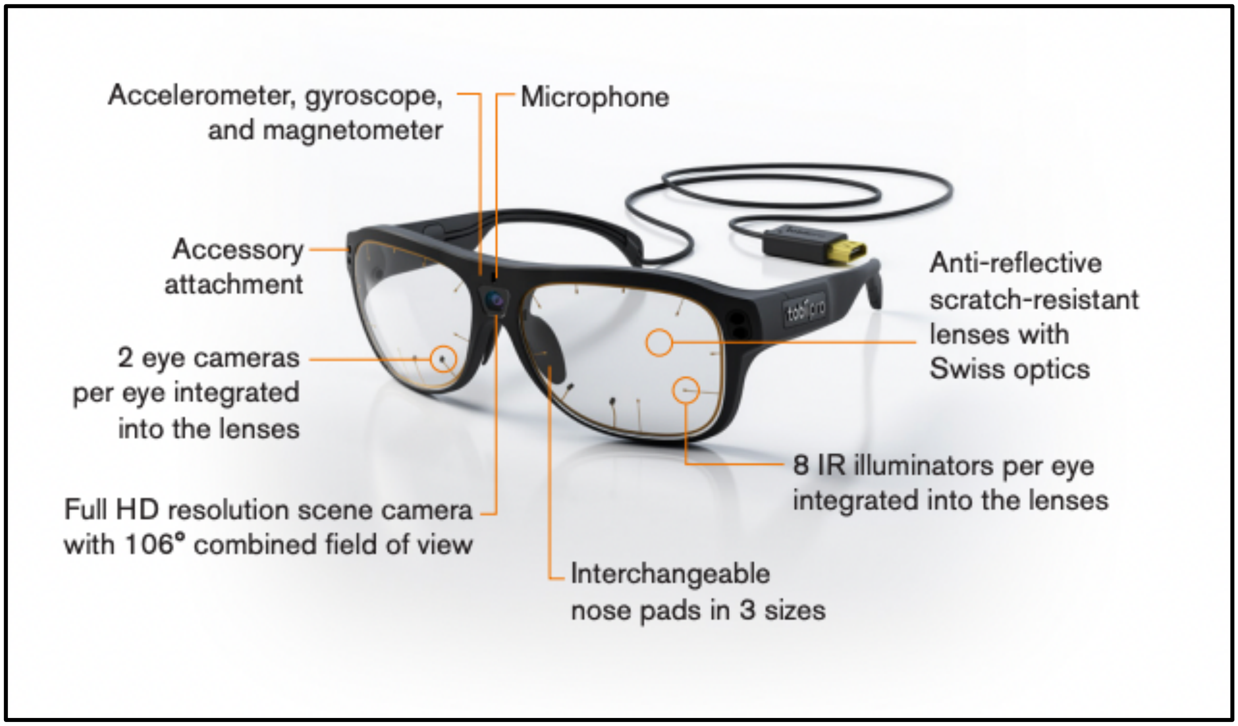
P -Drive

Notes during driving

Maneuvers	Follow regulations
Orientate	**Attending and acting (heeding)**

Appendix D

Tobii Pro Glasses 3 Diagram (Tobii Pro, 2021)



Appendix E

Tobii Pro Glasses 3 Technical Specifications (Tobii Pro, 2021)

Technical specifications

Eye tracking	
Eye tracking technique	Corneal reflection, dark pupil, stereo geometry
Binocular eye tracking	Yes
Sampling rate	50 Hz or 100 Hz
Calibration procedure	One point
Parallax compensation tool	Automatic
Slippage compensation	Yes, 3D eye tracking mode
Pupil measurement	Yes, absolute measure
Accuracy	0.6°

Head unit	
Material	Grilamid plastic, stainless steel, optical-grade plastic lenses
Nose pad	Grilamid plastic, with clip on attachments
Scene camera, video resolution	1920 × 1080 at 25 fps
Scene camera, video format	H.264
Scene camera, field of view (diagonal)	106 deg. 16:9 format
Scene camera, field of view (horizontal and vertical)	95 deg. horizontal / 63 deg. vertical
Weight	76.5 grams including cable
Frame dimensions (width ×depth ×height)	153 ×168 ×51 mm
Cable length	1200 mm
Audio	16-bit mono, integrated microphone
Design characteristics	Lightweight and discreet
Number of eye tracking sensors	4 sensors (2 per eye)
Fixed geometry	Yes
Sensors	ST™ LSM9DS1 sensors: Gyroscope and Accelerometer (sampled at 100 Hz); Magnetometer: (sampled at 10 Hz)
Input voltage and current rating	5.5Vdc max, 0.5A

Recording unit	
Battery recording time	105 min.
Battery type	Rechargeable 18650 Li-ion, Capacity: 3400 mAh
Storage media	SD (SDXC, SDHC) card
Connectors	Micro USB, RJ45 (Ethernet), 3.5 mm jack (sync port), head unit connector
Dimensions (height x width x depth)	130 x 85 x 27 mm
Weight	312 grams
Sync Port	3.5 mm jack (TTL signal)

Accessories*
Corrective Lenses
Clear Protective Lenses
Tinted Protective Lenses with IR blocking
Motion Capture Marker Set

Corrective Lenses*	
Corrective Lenses	32 pieces, ranging from −5.0 dpt. to +3.0 dpt. in increments of 0.5 dpt. Made of optical-grade plastic with hard coating
Dimensions (height x width x depth)	80 x 270 x 370 mm (complete kit)
Weight	1150 grams (complete kit)

Pro Glasses 3 controller app — system requirements			
Operating System	Windows 10 64-bit Professional or Enterprise, version 2004	Android OS version 9 or later	macOS 11 (Big Sur)
CPU	Intel® Core™ i5 dual core or later	Snapdragon 835 (8 cores, 2.0 GHz) or equivalent	Intel Core i-series
RAM	8 GB	6 GB	8 GB

Analysis software
Tobii Pro Lab*
Tobii Pro Glasses 3 API
Any application built on Pro Glasses 3 API

*purchased separately.

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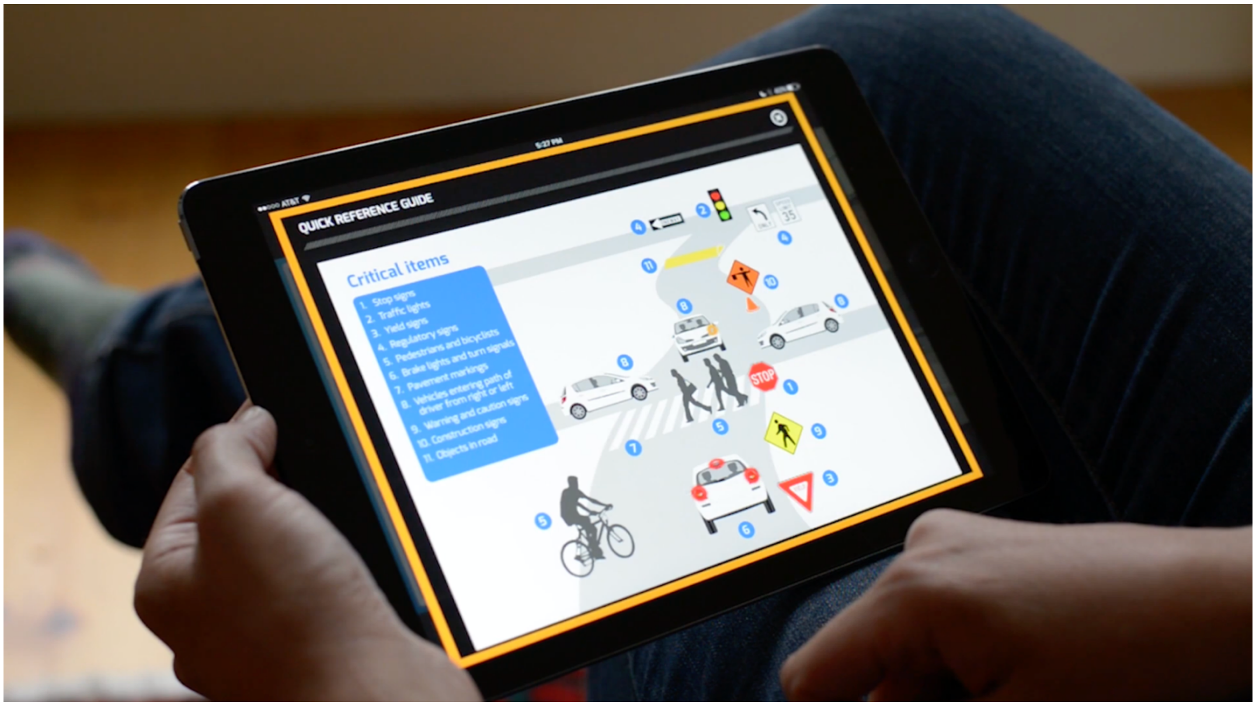
Tobii Pro provides eye tracking research solutions and services designed to deepen understanding of human behavior. Headquartered in Sweden, with local teams active on six continents, we help business and science professionals to further their research.

tobiipro.com
sales@tobii.com

tobii pro

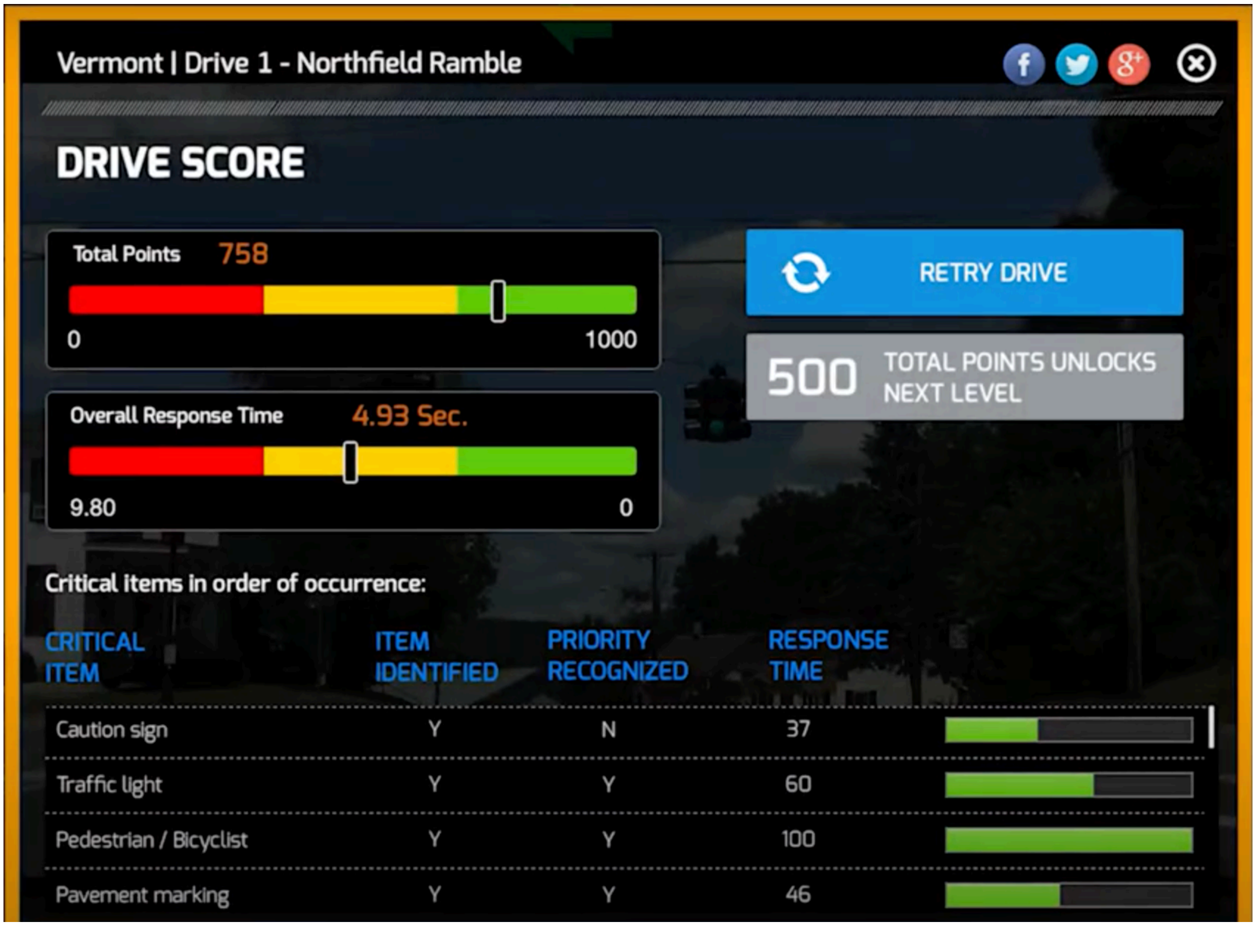
Appendix F

Drive Focus® Critical Items: Quick Reference Guide (Driver Rehabilitation Institute, 2020b)



Appendix G

Drive Focus® Example Score



Appendix H

Individual Variance in Adolescent/Adult Sensory Profile (AASP) Scores (N=14)

Score Category	**Low Registration**	**Sensation Seeking**	**Sensory Sensitivity**	**Sensation Avoiding**
Much Less Than Most People	0	1 I	0	0
Less Than Most People	0	6 C, E, F, L, M, N	0	0
Similar To Most People	8 A, D, E, F, I, K, L, M	5 A, B, D, G, K	10 A, B, D, E, F, H, I, K, L, N	4 A, B, D, E,
More Than Most People	4 B, C, H, N	1 H	1 M	5 F, H, I, L, N
Much More Than Most People	2 G, J	1 J	3 C, G, J	5 C, G, J, K, M