2017

A Comparison Of Novice And Experienced Drivers With Autism Spectrum Disorder

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A COMPARISON OF NOVICE AND EXPERIENCED DRIVERS WITH AUTISM SPECTRUM DISORDER

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A DISSERTATION

Submitted to the graduate faculty of The University of Alabama at Birmingham,
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

BIRMINGHAM, ALABAMA

2017

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LIFESPAN DEVELOPMENTAL PSYCHOLOGY PROGAM

ABSTRACT

According to recent estimates, only 33% of individuals with Autism Spectrum Disorder (ASD) successfully achieve licensure compared to nearly 84% of the general population. Despite this decreased number of individuals driving in the ASD population and the importance of driving in increasing independence and quality of life, research in transportation safety among drivers with ASD is limited. Many of the impairments associated with ASD such as anxiety, processing speed and executive function may negatively impact driving performance. This study is among the first to objectively assess possible demographic, cognitive and simulated driving performance differences in individuals with ASD who are still learning to drive and those with ASD who have successfully obtained a driver’s license. Participants included 9 individuals with a diagnosis of ASD still learning to drive (learner’s permit only). Pre-drivers were compared to 16 fully licensed drivers with ASD. Participants completed a simulated driving task, questionnaires, measures of driving anxiety and processing speed. Drivers with ASD had significantly more speed exceedances compared to pre-drivers. Age and experience emerged as a significant predictor of licensure status with greater age/experience predicting membership to the full license group. Driving anxiety and ASD symptom severity marginally predicted licensure status with greater levels of anxiety and higher ASD symptom severity associated with the fully licensed group. Mobility is a key component to independence and further research is needed to investigate the learning to drive process in individuals with ASD.

Keywords: Autism Spectrum Disorder, Driving, Anxiety, Speed of Processing, Neurodevelopmental disabilities

DEDICATION

This dissertation is dedicated to my family. To my husband who has seen me through every late night and every stressful day, you are the love of my life, and I couldn’t have done this without you. To my mom and dad who kept telling me to push forward to this day. You two are a constant source of love and inspiration. To my work family at the TRIP Lab, I will always treasure the laughs we had and struggles we conquered as a team. I will miss you all dearly. To my work mom and mentor, Dr. Stavrinos, thank you for all of the time and effort you have put into training me. You have not only made me a better researcher and scientist, but a better person. To God, thank you for the passion and love you have given me for people with disabilities. To You be all the glory. Finally, this dissertation is dedicated to all of the individuals and families in the Autism community who made this work possible. You are the real heroes.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support from the following sponsors of this work: the Civitan Emerging Scholars Whit Mallory Fellowship through the UAB Civitan International Research Center; the Lizette Peterson-Homer Memorial Injury Research Grant through the American Psychological Foundation; two Dwight David Eisenhower Transportation Fellowships through the U.S. Department of Transportation Federal Highway Administration; and the University of Alabama at Birmingham Department of Psychology. Use of the STISIM driving simulator was made possible by the UAB Edward R. Roybal Center for Translational Research in Aging and Mobility (NIH/NIA grant no. 5 P30 AG022838-09) and a grant from the National Institute on Aging (NIH/NIA grant no. 5 R01 AG005739-24). I would also like to thank the people and organizations that helped with study recruitment: Brooke Bowles (Triumph Services), Dr. Sarah Ryan (UA ACTS Program), Dr. Rachel Fargason (UAB Adult Psychiatry), Dr. Marsha Sturdevant (Children's of Alabama Adolescent Health Center), Paige Hebson, Craig Rogers and Yolanda Spencer (Vocational Rehabilitation Services of Alabama), Valerie Dubose (UAB Disability Support Services), Dr. Kristi Guest and Dr. Sarah O'Kelley (UAB Civitan Sparks Clinic) and Dr. Andrea Winslett (Grayson and Associates). Finally, I would like to thank the committee: Dr. Despina Stavrinos, Dr. Fred Biasini Dr. Rajesh Kana, Dr. Robin Lanzi and Dr. Marsha Sturdavent for their guidance throughout this process and the research assistants of the Translational Research for Injury Prevention Laboratory for their assistance with data collection and entry.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

One of the fastest-growing neurodevelopmental disabilities in the United States is Autism Spectrum Disorder (ASD) with a prevalence that has increased from 1 in 88 children in 2008, to 1 in 68 children in 2014 (Centers for Disease Control and Prevention [CDC], 2015a). ASD is characterized by deficits in social communication and social interaction, the presence of repetitive behaviors and restricted interests, and a complex combination of diminished and intact cognitive abilities (American Psychiatric Association [APA], 2014). The cognitive impairments in individuals with ASD include: (1) deficiencies in executive functioning (Faul, Erdfelder, Lang, & Buchner, 2007; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Hughes, Russell, & Robbins, 1994; Rinehart, Bradshaw, Brereton, & Tonge, 2001), (2) reduced attentional capacity (Bradley & Isaacs, 2006; Fan et al., 2012; Romer, Lee, McDonald, & Winston, 2014), (3) poor emotion regulation (Heerey, Keltner, & Capps, 2003; Jahromi, Bryce, & Swanson, 2013; Jahromi, Meek, & Ober-Reynolds, 2012), (4) impairments in processing speed (Calhoun & Mayes, 2005; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007), and (5) high levels of anxiety (Simonoff et al., 2008; White, Oswald, Ollendick, & Scahill, 2009). The majority of these impairments have been identified and studied in children with ASD, but research suggests that these impairments also persist into adolescence and adulthood; a period in which complex tasks like driving become an essential part of everyday living (Howlin, 2000; Lindsay, 2016; Luna et al., 2007).

Drivers with Autism

For children diagnosed on the high functioning end of the Autism Spectrum in the early 2000's, who will soon be approaching driving age, the decision to drive and the challenges that will accompany this task are nearing quickly (Centers for Disease Control and Prevention [CDC], 2015a). A recent study conducted in New Jersey however revealed that only 33% of adults with ASD reported that they were independent drivers (Curry, Yerys, Huang, & Metzger, 2017). This number is dramatically lower than the 87% of individuals in the general population who consider themselves to be independent drivers (U.S. Department of Transportation Federal Highway Administration, 2011). A recent pilot study investigating the self-reported driving behaviors of licensed drivers with ASD revealed that compared to non-ASD drivers, drivers with ASD report significantly lower ratings of their driving abilities, suggesting that they are less confident in their driving than typically developing controls (Daly, Nicholls, Patrick, Brinckman, & Schultheis, 2014). ASD participants in the same study also reported more intentional violations (e.g., speeding or tailgating), driving mistakes (i.e., making a maneuver without checking mirrors, pressing the wrong pedal), and slips or lapses than did typically developing controls. In another survey, the majority (70%) of parents who had adolescents with ASD who were driving or trying to receive their driver's license, reported that their child's autism "moderately" to "extremely" negatively impacted their child's driving abilities (N. B. Cox, Reeve, Cox, & Cox, 2012). These same parents identified multitasking (e.g., merging while maintaining speed), awareness of traffic, use of mirrors and maintaining lane position as the most difficult (rated as "very difficult') skills to teach their son or daughter with ASD (N. B. Cox et al., 2012). Turning, speed control, and braking were also rated as "difficult" tasks when teaching their child to drive. Parents also rated the impact of seven characteristics commonly associated with ASD on their adolescent's driving abilities, and reported that "non-verbal communication" and "unexpected changes in routine" were the most problematic for driving (N. B. Cox et al., 2012). A recent study examining driving skills that were most challenging in the learner phase for young drivers with ASD also found that adjusting to unfamiliar situations was one of the most commonly reported problematic skills (Almberg et al., 2015). Qualitative data from these studies echo many of the concerns that parents of teens with ASD have expressed in previous research.

Teens with ASD also self-reported "interacting with other drivers" and "interpreting traffic situations" as some of the most difficult driving skills (Almberg et al., 2015). When these same teens' driving instructors were questioned about the driving situations that were most challenging for their students with ASD, they cited the inflexibility and rule following characteristics of ASD as major barriers to driving. Throughout the limited number of previous research studies examining driving challenges in the ASD population two of the most commonly reported issues relate to the ability to quickly perceive and process information in the driving environment (i.e., formulating responses to the driving envrinoment and other drivers quickly) and issues related to driver's psychological barriers to driving (i.e., feeling of anxiety, worries about driving ability and safety). The impairments that accompany the diagnosis of ASD make the complex task of driving especially challenging, and the current study will focus specifically on two of these associated impairments: anxiety and poor processing speed.

Psychological Factor: Anxiety

Previous survey data have identified anxiety as one of the most commonly reported driving barriers for individuals with ASD (Almberg et al., 2015; N. B. Cox et al., 2012). Anxiety disorder presents as a disproportionate fear or adverse reaction to relatively nonthreatening environmental stimuli and is a common co-morbid condition seen in individuals with ASD (National Institute of Mental Health [NIMH], 2016; White et al., 2009). Although prevalence rates of anxiety disorders in the ASD population have been varied, ranging from 47 to 84% (Gillot, Furniss, & Walter, 2001; White et al., 2009), several studies have found higher rates of clinical and subclinical levels of anxiety in individuals with ASD as compared to typically developing groups (Bellini, 2004; Gillot et al., 2001; Vohra, Madhavan, & Sambamoorthi, 2016). Within the population of individuals with ASD, it has also been found that individuals with High-Functioning Autism (HFA) or Asperger's Syndrome (AS) exhibit particularly high levels of anxiety (Bellini, 2004; Gillot et al., 2001). It has been suggested that this is due to the highly cognitive nature of anxiety disorders; therefore individuals on the Autism Spectrum with higher IQ may experience greater levels of anxiety (Kelleher, 2013). This is an especially pertinent issue as they are the subgroup of individuals with ASD's who are mostly likely to drive independently (Curry et al., 2017; Lindsay, 2016).

There is a large body of literature suggesting that anxiety has a negative impact on general task performance (Hembree, 1988; Holdnack, Zhou, Larrabee, Millis, & Salthouse, 2011; Seipp, 2007). Several theories have been proposed to explain this relationship (Taylor, Deane, & Podd, 2008). One of the most popular of these theories is the Processing Efficiency Theory (PET), which posits that the worry and constant monitoring of potentially harmful stimuli reduce the efficiency of working memory, processing speed and subsequently task performance (Eysenck & Calvo, 1992). It has also been suggested however that some anxiety may actually improve task performance by increasing awareness and alertness (Taylor et al., 2008). Yerkes-Dodson's law outlines this more specifically and suggests a curvilinear relationship between anxiety and performance with some anxiety needed for adequate performance, but decrements in performance associated with high anxiety levels (Yerkes & Dodson, 1908). Several of the cognitive domains impacted by high levels of anxiety are critical to the task of driving including working memory and information processing (Beck & Clark, 1997; Eysenck & Calvo, 1992; Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010). One study examined the effects of anxiety on driving specifically and found that higher levels of trait anxiety were associated with more driving errors (i.e., failures of observation), lapses (i.e., absent-minded behaviors), violations (i.e., deliberate departures from safe driving behaviors) and aggressive violations (Shahar, 2009). Matthew and colleagues also investigated the effects of anxiety on driving and found more self-reported driving errors and poorer simulated driving performance (e.g., poor steering control) in individuals with high levels of driving anxiety (Matthews, Dorn, & Glendon, 1991; Matthews et al., 1998). As anxiety is a consistently reported problem in the population of individuals with ASD, it stands to reason that their elevated levels of anxiety may negatively impact their driving performance and may even keep them from getting a license (Chee et al., 2015; White et al., 2009).

Anxiety response comprises not only a psychological component as discussed above (Holdnack et al., 2011; Kantor, Endler, Heslegrave, & Kocovski, 2001), but also a physiological component (i.e., increased heart rate) (Mazurek et al., 2013). Physiological response to anxiety is commonly examined using various measures of cardiovascular function (Gorman & Sloan, 2000). More specifically, increased heart rate has been associated with increased anxiety while completing a task (Kantor et al., 2001). Previous research has also demonstrated that individuals with ASD often have elevated heart rates indicating increased nervous system activity, which is likely a result of the anxiety commonly seen in the disorder (Kootz & Cohen, 1981). This heightened state of arousal and consistently elevated heart rate may decrease their cardiovascular response (i.e., changes in heart rate) to stressful stimuli (Kootz & Cohen, 1981). Together, this literature suggests that the anxiety typically seen in ASD may result in elevated heart rate and difficulty in modulating heart rate during a task they perceive as stressful such as driving (Chee et al., 2015).

Cognitive Factor: Processing Speed

Visual processing speed has been defined as "the amount of time needed to make a correct judgment about a visual stimulus" (i.e., detecting a target, identifying a target's spatial location) (Owsley, 2013). As this ability is used constantly during the task of driving (e.g., detecting hazards in the environment, judging the spatial positions of other vehicles), visual processing speed is a key skill for navigating the driving environment safely (Anstey, Horswell, Wood, & Hatherly, 2012). Typically developing, experienced drivers are better able to quickly identify important, safety-relevant aspects of the driving environment (e.g., the cars in front of them, pedestrian crosswalks, traffic lights and road signs) when compared to novice drivers (Almberg et al., 2015; Borowsky, Shinar, & Oron-Gilad, 2010). A study by Crundall (2015) found that hazard perception (i.e., identifying hazardous targets in the driving environment) was less effortful for experienced drivers compared to novice drivers and this difference was even greater when the driving hazard was less obvious (e.g., a car pulling out of a hidden drive). Experienced drivers' increased attention to important areas of the driving environment and their ability to quickly scan the scene for hazards provides them with adequate information to drive safely and allows them to react more quickly to avoid these hazardous situations (Almberg et al., 2015; Borowsky et al., 2010). This visual processing speed has been shown in previous research to be underdeveloped not only in novice drivers, but also in individuals with ASD (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Yi et al., 2012).

In the real-world driving environment, the inability to rapidly process a great deal of visual information in an environment and identify important target items (e.g., traffic lights, other cars, pedestrians, stop signs, etc.) could result in an increased risk of motor vehicle collision. These decrements have been demonstrated not only in children with ASD (Yi et al., 2012), but processing speed impairments have also shown to persist into adolescence and adulthood; a time period when the task of driving becomes an important part of daily living (Luna et al., 2007). Adults with ASD have also self-reported difficulties in "processing fast-moving visual events", a description that certainly applies to the complex and dynamic nature of the driving environment (Gepner & Mestre, 2002). The combination of processing speed impairments already present in individuals with ASD along with the reduced efficiency of information processing caused by anxiety may make the task of driving especially difficult for this population. In addition to driving anxiety and impairments in processing speed, the inexperience of novice drivers with ASD may also serve as a barrier to obtaining a full driver's license.

Novice Drivers

Previous literature has identified a variety of factors that are known to increase driving risks for young, novice drivers such as incomplete development of the prefrontal cortex (a brain area involved in decision-making and other executive functioning skills) and inexperience (Compton & Ellison-Potter, 2008; Shope & Bingham, 2008; Williams, 2003). The executive function impairments already present in ASD may compound the developmental immaturity seen in novice, adolescent drivers (Luna et al., 2007). A study by Luna and colleagues (2007) examining the cognitive development of individuals with ASD compared to typically developing individuals revealed impairments in speed of processing and response preparation during cognitively demanding tasks. Driving is a prime example of a task that is not only cognitively demanding, but requires the driver to quickly process information and plan/execute responses (Anstey et al., 2012). Another salient factor putting novice drivers at risk is inexperience which contributes to young drivers' difficulty with the anticipation and identification of dangerous situations in the driving environment (McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009; Sagberg & Bjornskau, 2006). As a result of their inexperience, young drivers often have a more difficult time than experienced drivers identifying dangerous driving situations before they happen (Simons-Morton et al., 2011). Another study of visual information processing in novice vs. experienced drivers, revealed that novice drivers displayed slower visual processing in visually complex and demanding driving environments (i.e., a divided highway with forward-moving, merging and oncoming vehicles) (Crundall & Underwood, 1998). In some cases, they may even be aware of a hazard, but may underestimate the severity of the danger (Centers for Disease Control and Prevention

[CDC], 2015b). The impairment in quickly identifying dangerous situations places them at an increased risk for fatal motor vehicle collisions (MVCs). Crundall (2016) suggested that hazard prediction may be more cognitively demanding for novice drivers compared to experienced drivers as demonstrated by degradation in hazard prediction performance in novice drivers as time-on-task increased. This difference was even greater when prediction of the hazardous event was indirectly linked to the hazard (i.e., an ice cream van parked on the side of the road masking child pedestrians that might step into the street). Experienced drivers' increased attention to important areas of the real-world driving environment and their ability to quickly scan the scene for hazard precursors provides them with adequate information to react more quickly to avoid hazardous situations (Almberg et al., 2015; Borowsky et al., 2010). These findings further illustrate the important role driving experience plays in driving safety and mitigation of dangerous driving situations. The inexperience of novice, adolescent drivers in combination with the impairments specific to individuals with ASD (i.e., anxiety and impairments in processing speed) may make the task of obtaining a driver's license especially challenging for young drivers with ASD. Unfortunately, previous literature examining how these impairments may impact driving safety is limited to only a few studies.

Autism and Driving Research

Previous ASD and driving research has been varied in both the ASD population examined (i.e., non-drivers, pre-drivers and fully licensed drivers) and the findings. Reimer and colleagues (2013) were one of the first to test the driving capabilities of individuals with ASD using a driving simulator. Findings indicated that compared to matched, typically developing controls; drivers with ASD had significantly slower reaction times when identifying hazards with a response button. This is important when considering that delayed reaction time is a significant predictor of motor vehicle collision-related injury or death (Elander, West, & French, 1993). Eye tracking results in Reimer's study (2013) further revealed that drivers with ASD focused their eye gaze more on low stimulus areas of the driving environment (e.g., looking up towards the horizon where there are fewer cars) than high stimulus areas of the driving environment (e.g., directly at the car in front of them, at pedestrians walking to their right or left) (Reimer et al., 2013). This is particularly dangerous in a real-world driving environment as higher stimulus areas such as city streets and suburban streets are where hazards often occur for various reasons (e.g., more pedestrian crossings and intersections) (Moudon, Lin, Jiao, Hurvitz, & Reeves, 2011). Although Reimer and colleagues (2013) examined the vulnerable group of drivers with ASD compared to typically developing controls, they did not examine individuals at varying levels of driving experience, a factor identified by previous literature as having a significant impact on driving performance (Mayhew, Simpson, & Pak, 2003).

Cox and colleagues (2016) also conducted a recent driving simulator study in a population of individuals with ASD who had received their learner's permit (novice drivers). The goal of the study was to examine the role of executive function and basic motor skill in tactical driving performance in 17 individuals with ASD who were not yet fully licensed but had obtained a driver's permit compared to 27 typically developing controls who had just received their full driver's license. Results indicated that the ASD group exhibited poorer driving performance (i.e., increased swerving, increased lane changes) and decrements were further compounded with the addition of a working memory task. Findings of the study also suggested that the ASD group had significantly slower hand/arm reaction times (i.e., swerving) when compared to typically developing controls (S. M. Cox et al., 2016). Not only did the ASD and typically developing groups have inherent differences in driving experience (i.e., the ASD group had only permits while the typically developing group had obtained a full unrestricted license), but they also did not consider within-group variability in driving experience.

As a follow up to previous work, Cox and colleagues (2010b) also investigated the simulated driving performance of novice drivers with ASD and typically developing licensed, experience drivers. As the authors expected, novice drivers with ASD performed significantly worse on all measures of driving performance (i.e., excessively low speed, crashes, off-road driving, missed turns) and had significantly lower overall driving skill scores. Not only were the ASD group's driving skill scores statistically significantly poorer, they were nearly 6 standard deviations below driving skill scores of experienced, typically developing drivers (Naito, Matsui, Maeda, & Tanaka, 2010a). However, the significant deficits in simulated driving performance noted in the ASD group may have been due to the vast differences between the ASD and typically developing group in driving experience along with the added impairments associated with ASD.

Contrary to the findings of Cox and colleagues (2010b), a recent study of the on-road driving behavior of individuals with and without ASD revealed only certain areas of driving deficit (i.e., vehicle maneuvers, left turns) in drivers with ASD (Hurst, Mitchell, Kimbrel, Kwapil, & Nelson-Gray, 2007). Drivers with ASD performed superior to the typically developing group on driving behaviors related to rule following (i.e., using turn signals, checking for traffic at intersections) (Hurst et al., 2007). The mixed findings of the few studies that have been done on ASD and driving suggest that more research is still needed to characterize drivers with ASD and identify the impact of the impairments associated with ASD on driving performance.

A review of the current literature on ASD and driving identified several different barriers to driving unique to individuals with ASD. These barriers included: accessibility to transportation, the cost associated with public transportation, poor confidence in driving and safety risk in driving a vehicle (Lindsay, 2016). Overall, it was determined that individuals with ASD have shown impairments in general simulated driving performance and experience significant challenges with regard to all aspects of transportation (i.e., driving a car, riding in a car, using the public transit system). This review also highlighted the significant gaps in ASD and driving literature as well as the need for studies further investigating driving behavior in individuals with ASD (Lindsay, 2016).

Specialized training programs have shown success in helping individuals with cognitive limitations (mean IQ of sample= 71) to pass the learner’s permit portion of the driver’s test (Lanzi, 2005). A simplified approach to teaching individuals with cognitive impairment may also be successful in training individuals with ASD to obtain not only their learner’s permit, but also their full driver’s license. Driving facilitates mobility, which in turn increases the likelihood of those with ASD to be successfully employed, attend social gatherings and not have to rely as heavily on their parents or caregivers. Although public transportation is frequently used in large cities and urban areas, those with ASD in rural and suburban areas are forced to rely on family and friends for transportation (Gaylord, Abeson, Bosk, Timmons, & Lazarus, 2005). For individuals with ASD, the ability to drive themselves around would open the door to other opportunities to be independent such as independent living and employment. Renty and Roeyers (2006) found that the more independent adults with ASD feel, the greater the increase in their self-reported quality of life. Improving quality of life for individuals with ASD is extremely important as more and more children are being diagnosed and will later be faced with the challenges of living independently (Zablotsky, Black, Maenner, Schieve, & Blumberg, 2015). The ability to drive is vital for success in achieving the independent lifestyle desired by the majority of those with ASD (Gaylord et al., 2005). Previous literature suggests that individuals with ASD take longer to pass the on-road test to obtain independent license, with many never succeeding (Almberg et al., 2015; Feeley, 2010).

Curry and colleagues (2017) recently conducted one of the largest studies to date on driving licensure among individuals with ASD. They examined licensure rates and progression through licensure in a sample of approximately 600 New Jersey residents with ASD. They found that approximately one third of individuals with ASD acquired a driver’s license, but did so roughly 9 months later than typically developing individuals. Promisingly, about 90% of individuals with ASD who obtained a learner’s permit also obtained a license within the next two years. This study also identified a discrepancy in the number of individuals with ASD who were interested in/planning on driving and the current licensure rates in this population (Curry et al., 2017). There is however, little research to explain why this may be the case.

Specific Aims

To my knowledge, the current study was the first to investigate the difference in cognitive factors and driving performance differences between permitted and fully licensed drivers with ASD. Unlike previous studies that have examined the driving behavior of adolescents and adults with ASD (Classen, Monahan, & Hernandez, 2013; S. M. Cox et al., 2016; Reimer et al., 2013), the current study was the first to examine novice, permitted drivers with ASD to identify demographic, psychological and cognitive factors that may be contributing to their inability to achieve full licensure. Further, the current study was also the first to examine driving anxiety and processing speed as predictors of licensure status (learner's permit or full license). Currently, many individuals with ASD are able to pass the knowledge portion of the driver test to obtain a learner's permit, but are unable to pass the on-road driving test to obtain a full license (provisional or unrestricted) despite meeting age and legal requirements (Chee et al., 2015; Huang, Kao, Curry, & Durbin, 2012; Lindsay, 2016). The current study aimed to identify the factors that may be keeping these individuals from obtaining an independent driver's license. The following specific aims were tested:

AIM 1: Compare the driving performance of novice drivers with ASD and experienced drivers with ASD.

Driving performance was measured using five driving performance indicators collected by a driving simulator: (1) root mean square (RMS) or standard deviation of lane position, (2) reaction time, (3) simulated MVCs, (4) speed fluctuation, and (5) number of speed exceedances. The effect of group (pre-driver or driver) on continuous measures of driving performance (RMS, reaction time and speed fluctuation) was tested using Analysis of Covariance (ANCOVA) controlling for group differences on age and driving experience. Due to the rare nature of the count variables (i.e., simulated MVCs and number of speed exceedances), a Generalized Linear Model (GLM) using the Poisson distribution was used to examine the effect of group on simulated MVCs and speed exceedances. The current study first aimed to examine whether or not pre-drivers with ASD had similar driving abilities compared to drivers with ASD and were not yet driving due to other factors.

Hypothesis 1. Based on the findings of Crundall (2016), Mayhew (2003) and Cox et al. (2016) it is expected that pre-drivers with ASD will have a poorer driving performance (slower reaction times, more simulated MVCs, greater deviations in lane position (RMS), greater fluctuations in speed and more speed exceedances) than drivers with ASD.

AIM 2: Identify significant predictors of licensure status of individuals with ASD.

Many of the impairments associated with ASD such as anxiety and speed of processing have been implicated as potential culprits behind the impairments in driving performance noted in drivers with ASD (Classen et al., 2013; Huang et al., 2012; Reimer et al., 2013). However, no study has examined the ability of inexperience, visual processing speed and anxiety to predict licensure status. Predictors of licensure status (permit only or license) included: age and experience; self-reported and physiological driving anxiety; visual processing speed; and ASD severity.

Possible predictors were tested using a stepwise logistic regression to predict licensure status. The first step included demographic variables (age and driving experience), step two included ASD symptom severity, and the final step included psychological and cognitive predictors (driving anxiety and processing speed).

Hypothesis 2a. There is a significant body of literature examining the impact of age and driving experience on simulated driving performance suggesting that driving performance improves with both age and experience (Borowsky, Oron-Gilad, Meir, & Parmet, 2012; Crundall, 2016; McCartt et al., 2009). Based on this literature it is expected that individuals with ASD who are older and have more experience will be more likely to have obtained a full license.

Hypothesis 2b. Based on data collected by Classen and colleagues (2013) suggesting that participants with ASD had poorer driving performance along with the self-reported decreased driving capabilities of drivers with ASD from the online survey study (Daly et al., 2014), it was expected that ASD symptom severity would significantly predict licensure over and above age and experience. Specifically, we expect that individuals with lower symptom severity scores be more likely to have obtained a full license.

Hypothesis 2c. Based on previous literature demonstrating the negative impact of anxiety on general task (Eysenck & Calvo, 1992), and driving performance (Matthews et al., 1998; Shahar, 2009), it is expected that lower driving anxiety will significantly predict full licensure status. As visual processing speed is a skill that is vital to the task of driving (Anstey & Wood, 2011), it is also expected that individuals with faster visual processing speed will be more likely to belong to the fully licensed group.

METHOD

Participants

The total sample consisted of 25 individuals: 16 drivers with a clinical diagnosis of ASD and 9 pre-drivers with a clinical diagnosis of ASD. All pre-drivers with ASD were over the legal age requirement for obtaining a driver's license (M_{age} = 17.56, *SD* = 1.94). The majority of the sample was male (approximately 80%) as expected given the distribution of ASD prevalence in the general population, with ASD being five times more common in males than females (Centers for Disease Control and Prevention [CDC], 2015a). As ASD occurs equally in all racial and ethnic groups, ethnic distributions were that of the local area (approximately 75% Caucasian) (Centers for Disease Control and Prevention [CDC], 2015a). Participants with ASD were recruited from flyers, advertisements on social media, and also from several organizations addressing the needs of individuals with neurodevelopmental disabilities.

General Study Inclusion/Exclusion Criteria

Exclusion criteria for the study were: (1) diagnosis of any severe psychiatric conditions (e.g., bipolar disorder) and (2) presence of severe physical disabilities (e.g., need for a wheelchair) which would prohibit full participation in the experimental protocol. Inclusion criteria were (1) age at least 15 and no older than 30 years of age; (2) having passed the on-road driving test (license) or knowledge test (permit) (depending upon group); (3) and the ability to read, write and comprehend English. ASD is commonly accompanied by other neurodevelopmental disabilities, with co-occurrence of one or more non-ASD neurodevelopmental diagnoses occurring in 83% of those diagnosed with ASD (Centers for Disease Control and Prevention [CDC], 2015a). For this reason, participants with a co-occurring developmental disability were not excluded from the study. Participants also had to have a previous diagnosis of Autistic disorder, Asperger's syndrome, Pervasive Developmental disorder not otherwise specified or Autism Spectrum Disorder from a licensed clinical psychologist or medical doctor.

Measures

Driving Simulator

Study participants engaged in a computerized driving simulation task to measure performance under specified conditions of interest (STISIM Drive, Systems Technology Inc., Hawthorne, CA). The simulation was displayed on three, 20" LCD computer monitors. The simulator provided a view of the roadway and dashboard instruments, including a speedometer, rpm gauge and a letter indicating the vehicle's gear. The vehicle was controlled by moving a steering wheel in a typical driving manner while depressing the accelerator and brake pedals accordingly. An on-board stereo sound system provided naturalistic engine sounds, external road noise, and sounds of passing traffic.

Driving Scenarios. The driving scenario featured a two-lane, bi-directional road enhanced by daytime suburban scenery. The scenario was standardized by distance (5 miles) and varied in posted speed limit, so participants could differ in the time it took them to complete the drive (on average approximately 10 to 15 minutes). During the scenarios, participants navigated through an environment containing a total of eight hazards (e.g., a pedestrian darted into the street, a lead vehicle stopped suddenly) that required an immediate response. Hazardous events were defined as unexpected events that required the driver to brake, speed up or make some type of evasive maneuver to avoid a collision. These were modeled after previous research efforts (Sheppard, Ropar, Underwood, & Van Loon, 2010). Events were triggered when the driver was at a certain distance (determined by simulator software) away from the hazard.

Driving Performance. The simulator provided five indicators of driving performance:

(1) RMS indicated the deviation of lane position and provided a sensitive measure of driving precision (Marcotte et al., 2003; Stavrinos et al., 2015). RMS served as an indicator of the degree of adjustment the driver implemented to maintain a desired position within the lane. Greater within-lane deviation indicated poorer driving precision.

(2) Reaction time reflected the amount of time in seconds that elapsed from the time the event triggered to the first of four possible reactions: a 10% increase in accelerator pressure (i.e., the driver began to depress the accelerator to speed up), a 10% decrease in accelerator pressure (i.e., the driver began to release the accelerator to slow down) (Rakauskas, Gugerty, & Ward, 2004; Stavrinos et al., 2015), an increase of at least 1 pound of pressure to the brake pedal (i.e., driver began to press the brake to slow the vehicle) (Crundall, Andrews, van Loon, & Chapman, 2010; Garrison & Williams, 2013), or a 5-degree change in steering wheel angle (i.e., the driver swerved to avoid the hazardous event) (Crundall et al., 2010; Garrison & Williams, 2013).

(3) Standard deviation of speed was also collected and served as a measure of deviation in average driving speed, which provided a measure of compensatory slowing

and speeding up (Stavrinos et al., 2013; Stavrinos et al., 2015). Greater standard deviation of speed indicated poorer driving performance.

(4) Total number of simulated motor vehicle collisions (MVCs) was computed across each driving scenario as anytime the participant ran off the road or struck another vehicle, pedestrian, cyclist or object (Narad et al., 2013; Stavrinos et al., 2015).

(5) Number of speed exceedances was defined as the number of times the participant exceeded the speed limit greater than or equal to 8 miles per hour while driving through the scenario (Bishop, Biasini, & Stavrinos, 2017).

Sample Characteristics

Demographics. Participants were asked via telephone screening to provide basic demographic information including age, gender, race, the highest level of education completed, co-morbid conditions, number of medications, months since permit was received (indicator of driving experience) and average days driven per week (indicator of driving exposure).

Attention-Deficit/Hyperactivity Disorder Symptoms. The self-report version of the Disruptive Behavior Rating Scale (DBRS) was used to assess the presence of ADHD symptoms (Barkley & Murphy, 1998; Erford, 1993). This 18-item questionnaire assessed the frequency of ADHD inattentive and impulsivity symptoms. The inattentive subscale was composed of 9 items addressing inattention (e.g. "I am easily distracted") while the second impulsivity subscale was composed of 9 items dealing with hyperactivity/impulsivity symptoms (e.g., "I have difficulty awaiting my turn"). Each item, or behavior, was rated on a 4-point Likert scale from 0 (*never* or *rarely*) to 3 (*very often*) with higher scores indicating greater ADHD symptom severity (Barkley &

Murphy, 1998; Silva et al., 2005). A summed symptom severity was computed for each subscale ranging from 0 to 9 for Inattentive (Cronbach's $\alpha = .79$) and Hyperactive/Impulsive (Cronbach's $\alpha = .77$). Total ADHD symptom severity scores were collected by summing the Inattention and Hyperactivity/Impulsivity scales, yielding a score from 0-54 (Cronbach's $\alpha = .85$).

Possible Predictors

Autism Spectrum Disorder Symptomology. The Autism-Spectrum Quotient (AQ) questionnaire was used to assess the presence of Autism symptom severity (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006). The AQ is a 50 item questionnaire comprised of 5 sets of 10 questions that assessed five different areas of ASD symptomology: social skill, attention switching, attention to detail, communication and imagination, with higher scores indicating a greater presence of autistic characteristics (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The AQ was scored to produce an ASD symptom severity score for each participant (Lundqvist & Linder, 2017). Each question was answered on a scale from "definitely agree" to "definitely disagree". Items were scored from 1 to 4 such that an answer of "definitely agree" for a question consistent with ASD characteristics would yield a score of 4 (i.e., I have very strong interests, which I get upset about if I cannot pursue"). Approximately half of the items were phrased such that an answer of "definitely agree" would indicate inconsistency with ASD characteristics (i.e., "I find social situations easy."). These items were reverse scored such that an answer of "definitely agree" for these questions yielded a score of 1. This likert scoring method has been shown to improve variability, reliability and validity of the measure in comparison to the binary scoring method (Stevenson &

Hart, 2017). Discriminative power tests of the AQ revealed a successful differentiation rate of 80% (Naito et al., 2010a). For the current study, internal consistency was good (Chronbach's alpha = .841).

Processing Speed. *Useful Field of View®*. The computerized, three subtests of the Useful Field of View (UFOV®) were administered to all participants as a measure of visual processing speed (Ball, Owsley, Sloane, Roenker, & Bruni, 1993). Subtest 1 is a measure of processing speed. It requires participants to focus on a focal point in the center of the computer screen (i.e., a white box), then discriminate between stimulus that is presented very quickly on a computer screen. Subtest 2 is a measure of divided attention and requires the subject to again focus on a central object, then discriminate a central object (car or truck) while simultaneously locating an object in the periphery. Subtest 3 is a measure of selection is identical to subtest two, but with the addition of distractor objects in the participant's periphery. A depiction of each of the subtests can be found in Figure 1. The test automatically adjusted the length of the stimulus presentation (in milliseconds) as the participant responded to calculate a perceptual threshold for each subtest. These threshold scores were summed to create an overall UFOV® score such that lower scores indicate faster visual processing speed (Vance, Fazeli, Ball, Slater, & Ross, 2014). UFOV® has demonstrated good reliability (UFOV®1 r= .72; UFOV®2 r= .81; UFOV®3 r= .80; UFOV® total r= .88) (*UFOV User's Guide*, 2009). UFOV® has also been well-validated as an excellent predictor of motor vehicle collision risk in a variety of populations (Clay et al., 2005). The ability to quickly scan and search for specific items has been shown by previous research to be impaired in adolescents with ASD, and impaired performance on UFOV® have shown to be a significant predictor of poorer driving performance in drivers with ASD when compared to control drivers (Monahan, Classen, & Helsel, 2013).

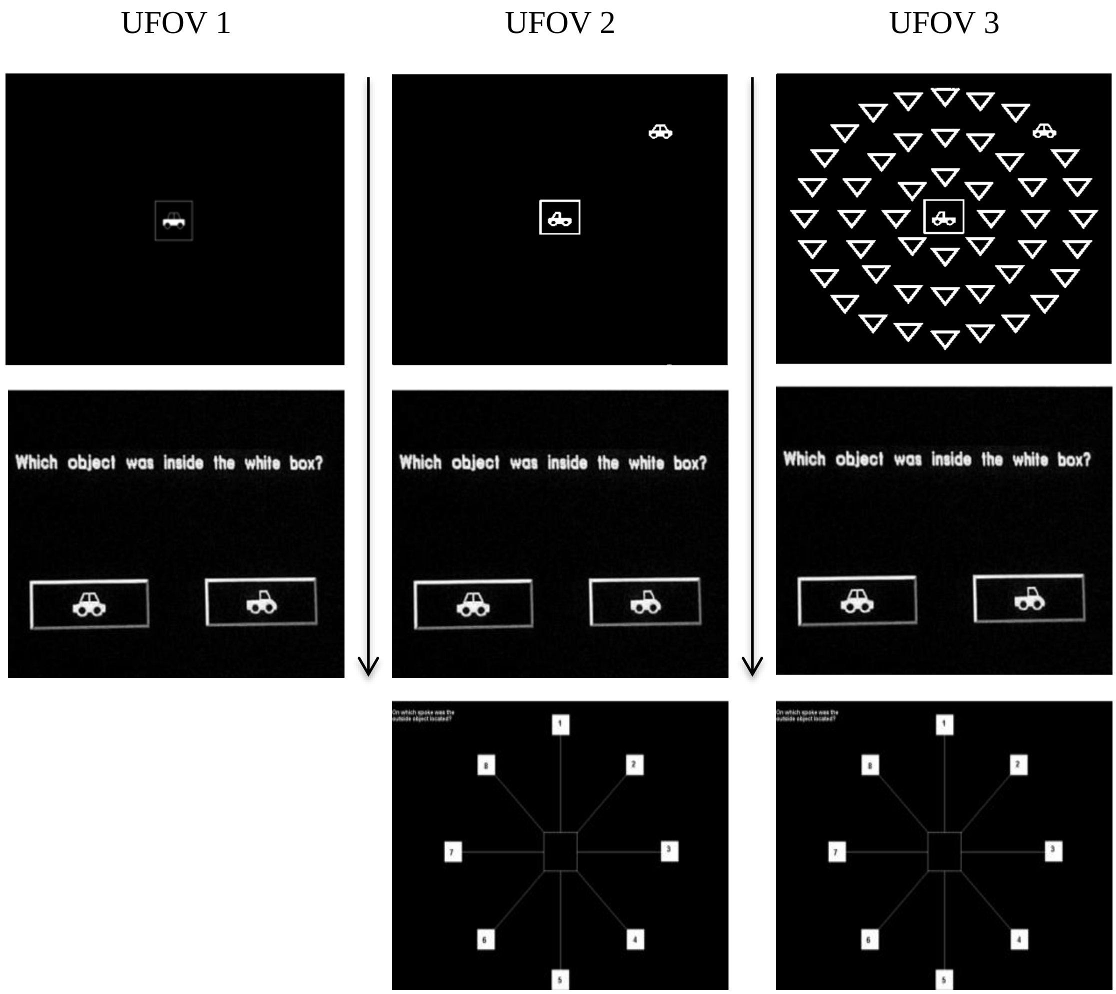

Figure 1. *Useful Field of View.* Adapted from "Patterns of Abnormal Visual Attention in Myalgic Encephalomyelitis" by C.V. Hutchinson and S.P. Badham, 2013, Optometry and Vision Science, 90, p. 608.

Self-reported Driving Anxiety. *Scale for Apprehensive Driving.* Scale for Apprehensive Driving (SAD) questionnaire was used to assess self-reported driving anxiety. The SAD is a 17 item questionnaire comprised of 3 sets of questions that assessed positive and negative attitudes during 3 phases of driving: talking about driving, preparing to drive and while driving (Ross et al., 2016). The current study utilized only the negative items as an assessment of driving anxiety. Negative items (i.e., "Gets distracted with worries about not being able to drive safely") were rated on a scale of 0 ("Not at all") to 3 ("A Lot"). Previous research using the SAD in a population of typically developing individuals as well as individuals with ASD revealed high Cronbach's alpha coefficients for both groups (α= .85; α= .90) (Ross et al., 2016). The measure as a whole had good internal consistency in the current study's sample (Cronbach's α= .80) as did the items comprising the negativity subscale (Cronbach's α= .91) SAD total negative score was used as a measure of self-reported driving anxiety.

Physiological Driving Anxiety. *Polar Activity Band.* Heart rate during the simulated driving task was measured using a Polar RCX5 heart rate monitor. The monitor consisted of recording electrodes and a transmitter, which were attached to participants with an elastic strap, and a receiver and data storage device in the form of a wristwatch. The transmitter was worn around the chest at the level of the xyphoid process, underneath all clothing and in direct contact with the skin. The wrist receiver watch was located in the simulator room, approximately 1 meter away from participants. A button on the heart rate monitor initiated and later terminated recording at the beginning and end of the driving task. Average heart rate for that time interval was stored on the watch and was later transferred to an electronic database. Previous studies have used heart rate as a measure of anxiety (Reimer, Mehler, Coughlin, Roy, & Jusek, 2010) and have found significant correlations between average heart rate and self-reported anxiety (Kantor et al., 2001).

Although self-reported driving anxiety and physiological anxiety were not highly correlated in the current study, an overall composite driving anxiety variable was created based on theoretical bases underlying the various components of anxiety response (i.e., physiological and psychological) (Eysenck & Calvo, 1992) and to reduce the number of predictors in the logistic regression model on the study's small sample size. The composite anxiety score was calculated by summing the z-scores of self-reported driving anxiety (as measured by SAD total negative score) and physiological driving anxiety (as measured by AHR).

Procedure

A team graduate and undergraduate research assistants administered telephone screenings and certified graduate students administered tasks and questionnaires to all participants. Standardized experimental protocols were followed in all testing sessions. Participant eligibility for the study was based on information acquired during a pre-visit telephone screening process conducted by a trained research assistant. Telephone screenings for ASD participants were used to collect basic demographic information (e.g., age, gender, and years of education) as well as driving experience (e.g., months since driving permit was received). For control participants, telephone screenings were conducted to collect basic demographic information as well as match participants on age, gender and driving experience to ASD participants. Participants meeting eligibility for the study were scheduled for a study visit and mailed a packet including consent form, instructions for the visit, directions to the lab, and a series of questionnaires to complete.

Prior to study participation, upon arrival, each participant provided written informed consent, and parents provided consent for participants under the age of 18.

Upon arrival, participants were asked to wear a Polar activity sensor band to record heart rate and received instruction in the operation and use of the driving simulator during a calibration session prior to actual data collection. Preprogrammed, audible instructions provided participants information about the route to take while completing the driving task (e.g., “Turn left at the next intersection”). Participants drove a brief (1 mile), standardized simulator scenario until they achieved stable driving performance (no collisions and fewer than 2 speed warnings). Participants received verbal warnings if they drove too far below or above the posted speed limit. Participants were offered three attempts to complete the calibration drive. Participants who were unable to complete the calibration drive were deemed unfit for participation and did not proceed any further with the study. However, all participants were able to meet the minimum level of proficiency. There were no incidences of simulator sickness.

Participants then engaged in the experimental driving task consisting of one, five mile driving scenario with eight hazardous events distributed throughout the scenario. The driving scenario lasted approximately 15 minutes when driven at the posted speed limit. After completing the drive, each participant completed a series of questionnaires and tasks assessing processing speed and anxiety. At the conclusion of the session, participants were compensated $25.00 for their time.

DATA ANALYSES

Preliminary Analyses

Means and standard deviations of all variables were examined using descriptive statistics analyses in SPSS version 23. Distributions of variables were inspected and tests of normality, missingness, skewness and kurtosis were conducted. Bivariate correlations were also conducted to examine associations among variables. Missing data were handled appropriately according to the type of missingness pattern observed. Outliers were identified as observations that exceed three standard deviations from the mean. All values exceeding three standard deviations were excluded from data analysis. Non-normal distributions were adjusted, transformed or analyzed accordingly. Both *p*-values and effect sizes are reported for all analyses with *p*-values less than .05 considered significant.

Primary Analyses

AIM 1: Compare the driving performance of novice drivers with ASD and experienced drivers with ASD.

The effect of group (pre-driver or driver) on continuous measures of driving performance (RMS, reaction time and speed fluctuation) was tested using Analysis of Covariance (ANCOVA) controlling for group differences on age and driving experience. Due to the rare nature of the count variables (i.e., simulated MVCs and number of speed

exceedances), a Generalized Linear Model (GLM) with a Poisson distribution will be used to examine the effect of group on simulated MVCs and speed exceedances.

AIM 2: Identify significant predictors of licensure status.

Predictors of driving status were tested using a stepwise logistic regression to predict licensure status. The first step included demographic variables: participant's age and driving experience (as measured by months since permit was received), step two included ASD symptomology (as measured by AQ symptom severity score), and the final step included a composite driving anxiety score and processing speed (as measured by UFOV total score).

RESULTS

Overall Demographics

Data from 25 participants (16 drivers and 9 pre-drivers) were collected with participants having an average age of 21.60 years (*SD* = 4.41), 88% being male and 84% reported to be Caucasian. Participants had an average education level of 12.16 years (*SD* = 1.93). Participants reported driving an average of 3.96 days per week (*SD* = 2.82) and had an average of 67.44 months (or about 5.62 years) of driving experience (*SD* = 56.43). On average, participants had 1.28 (*SD* = 2.19) comorbid diagnoses. The most commonly reported comorbidities among participants included Generalized Anxiety Disorder, Depression and Obsessive Compulsive Disorder. Two participants (8%) reported having a diagnosis of Generalized Anxiety Disorder and one participant reported having a Social Anxiety Disorder Diagnosis. All three participants with self-reported anxiety diagnoses were in the driver group. Participants had an average AQ severity score of 82.60 (*SD* = 16.26) which is slightly lower than severity scores seen for ASD participants in previous research studies (Stevenson & Hart, 2017). ADHD symptom severity measures revealed an average total severity score of 17.76 (*SD* = 8.70), inattention severity score of 7.6 (*SD* = 4.73) and an impulsivity severity score of 10.16 (*SD* = 5.17). Although none of the participants had a formal ADHD diagnosis and there were no significant differences between the driver and pre-driver group, overall participants did demonstrate elevated ADHD symptomology, particularly impulsivity (Erford, 1993). Overall participants were prescribed an average of 2.28 medications (*SD* = 1.82). See Table 1 for descriptive statistics of overall participant characteristics and participant characteristics by group.

Pre-driver Demographics

On average pre-drivers were 17.56 years old (*SD* = 1.94), 78% male and 89% reported Caucasian Race. Participants had an average education level of 10.44 years (*SD* = 1.13). Pre-drivers reported driving an average of 3.33 days per week (*SD* = 3.00) and had an average of 17.56 months (or about 1.46 years) of driving experience (*SD* = 16.85). On average, pre-drivers had 0.89 (*SD* = 0.93) comorbid diagnoses. The most commonly reported comorbidities among pre-drivers included Obsessive Compulsive Disorder and Learning Disability. Pre-drivers had an average AQ severity score of 70.89 (*SD* = 16.48) which is slightly lower than severity scores seen for ASD participants in previous research studies (Stevenson & Hart, 2017). ADHD symptom severity measures revealed an average total severity score of 21.56 (*SD* = 8.73), inattention severity score of 9.11 (*SD* = 4.37) and an impulsivity severity score of 12.44 (*SD* = 4.79). Although none of the participants had a formal ADHD diagnosis, participants did demonstrate elevated ADHD symptomology, particularly impulsivity (Erford, 1993). Overall pre-drivers were prescribed an average of 2.89 medications (*SD* = 1.90).

Table 1. *Demographics*

Variables	Overall (n=25)			ASD Drivers (n=16)			ASD Pre-drivers (n=9)			
	M (SD)	*n* (%)	Range	*M (SD)*	*n* (%)	Range	*M (SD)*	*n* (%)	Range	t or χ^2
Demographic variables										
Age (Years)	21.60(4.41)	-	16-30	23.88 (3.70)	-	17-30	17.56 (1.94)	-	16-22	**$t(23) = 4.74$, $p < .001$**
Gender (Male)	-	22 (88%)	-	-	15 (94%)	-	-	7 (78%)	-	$\chi^2(1) = 1.39$, p=.24
Race (Caucasian)	-	21 (84%)	-	-	13 (81%)	-	-	8 (89%)	-	$\chi^2(1) = .612$, p= .74
Education (Years)	12.16 (1.93)	-	9-16	13.13 (1.59)	-	10-16	10.44 (1.13)	-	9-12	**$t(23) = 4.46$, $p < .001$**
Employed (Yes)	-	9 (36%)	-	-	7 (44%)	-	-	2 (22%)	-	$\chi^2(1) = 1.159$, p= .28
Months since learner's permit	67.44 (56.43)	-	1-187	95.50 (51.01)	-	11-187	17.56 (16.85)	-	1-52	**$t(23) = 4.41$, $p < .001$**
Days per week driven	3.96 (2.82)	-	0-7	4.31 (2.75)	-	0-7	3.33 (3.00)	-	2-7	$t(23) = 0.83$, p= .42
Clinical variables										
Number of Meds	2.28 (1.82)	-	0-7	1.94 (1.73)	-	0-7	2.89 (1.90)	-	0-5	$t(23) = -1.27$, p=.22
Comorbid Diagnoses	1.28 (2.19)	-	0-11	1.50 (2.66)	-	0-11	0.89 (0.93)	-	0-3	$t(23) = .662$, p=.52
AQ Total Severity Score	82.60 (16.26)	-	46-117	89.19 (12.23)	-	72-117	70.89 (16.48)	-	46-94	**$t(23) = 3.17$, $p < .01$**
DBRS Total Score	17.76 (8.70)	-	2-36	15.63 (8.18)	-	2-25	21.56 (8.73)	-	10-36	$t(23) = -1.21$, p=.24
DBRS Inattentive Score	7.60 (4.73)	-	0-15	6.75 (4.85)	-	0-15	9.11 (4.37)	-	2-15	$t(23) = -1.72$, p=.09†
DBRS Impulsivity Score	10.16 (5.17)	-	0-21	8.88 (5.06)	-	0-18	12.44 (4.79)	-	5-21	$t(23) = -1.69$, p=.10

Note: M = Mean, *SD* = Standard Deviation, AQ = Autism Spectrum Quotient, DBRS= Disruptive Behavior Rating Scale. **Bold**= $p < .05$. † = Marginal significance ($p < .10$).

Driver Demographics

Participants in the driver group were on average 23.88 years old (*SD* = 3.70), 94% male and 81% reported Caucasian Race. Participants had an average education level of 13.13 years (*SD* = 1.59). Drivers reported driving an average of 4.31 days per week (*SD* = 2.75) and had an average of 95.50 months (or about 7.92 years) of driving experience (*SD* = 51.09). On average, drivers had 1.50 (*SD* = 2.66) comorbid diagnoses. The most commonly reported comorbidities among drivers included Generalized Anxiety Disorder and Depression. Drivers had an average AQ severity score of 89.19 (*SD* = 12.23) which is slightly lower than severity scores reported for ASD participants in previous research studies (Stevenson & Hart, 2017). ADHD symptom severity measures revealed an average total severity score of 15.63 (*SD* = 8.18), inattention severity score of 6.75 (*SD* = 4.85) and an impulsivity severity score of 8.88 (*SD* = 5.06). Although none of the participants had a formal ADHD diagnosis, participants did demonstrate elevated ADHD symptomology, particularly impulsivity (Erford, 1993). Overall drivers were prescribed an average of 1.94 medications (*SD* = 1.73).

Demographic Group Differences

The pre-driver group (*M* = 17.56, *SD* = 1.94) was significantly younger than the driver group (*M* = 23.88, *SD* = 3.70), $t(23) = 4.74$, $p< .000$. Although significantly younger than the fully licensed group, all participants (100%) in the pre-driver group were eligible based on the age requirement in the state of Alabama to receive a full license (16 year old or older), but had not done so for other reasons discussed below. As expected, the pre-driver group (*M* = 17.56, *SD* = 16.85) also had significantly fewer months of driving experience compared to drivers (*M* = 95.50, *SD* = 51.09), $t(23) = 4.41$, *p*< .000. There were no significant differences among the groups for gender (χ^2(1) = .238, *p*= .530) or race (χ^2(2) = .612, *p*= .736). There were also no significant differences among the groups for number of comorbid diagnoses (*t*(23) = .662, *p*=.515). No significant differences were seen in the average number of days per week driven by pre-drivers (*M* = 3.33, *SD* = 3.00) compared to drivers (*M* = 4.31, *SD* = 2.75), *t*(23) = .828, *p*< .416.

Missing Data

Data from 25 individuals were available for analysis and inspection of frequencies revealed only one missing value from the variable UFOV1. The linear interpolation method was used in SPSS to replace the missing value. This imputed value was then used to calculate that participant's UFOV total score (Wise, Smith, & Rabins, 2017). Further inspection revealed no missing data for the independent variables or driving performance outcomes (RMS, reaction time, standard deviation of speed, average driving speed, simulated MVCs and speed exceedances).

Assumptions

Table 2 provides descriptive statistics for all predictor and driving outcome variables. The outcome variable speed exceedances had an overdispersed distribution (i.e., the variance was larger than the mean) and violated the Shapiro Wilks test for normality (*p*= .020). Simulated MVCs had a variance that was slightly smaller than the mean and violated the Shapiro Wilks test for normality (*p*= .028). For these reasons, Poisson distributions were used to analyze group differences in speed exceedances and MVCs. RMS, reaction time and standard deviation of speed were all normally distributed. All outcome and predictor variables were within the acceptable ranges for skewness and kurtosis.

Outliers

There was one outlier for the demographic variable “number of comorbid diagnoses”. One participant with ASD had 11 co-morbid diagnoses (Z= 4.44), however as numerous co-morbid conditions are common in the ASD population, this individual was retained in all analyses (Leyfer et al., 2006). Finally, there was one outlier for the predictor variable RMS (Z = 3.05). Analyses were conducted with and without this outlier to determine how the data were affected and no significant differences were found. For this reason, and to provide a more complete dataset, all results provided include this outlier. Levene’s Test for homogeneity of variances revealed no violations.

Correlations

Age and months since learner’s permit was received were significantly correlated (r = 0.932, p < .0001) indicating multicollinearity. Given the importance of age and driving experience to driving performance and the inherent differences in age and experience between the groups of the current study, an age/experience variable was included as covariate in all analyses examining differences among driver groups (Borowsky et al., 2010; Crundall, 2016; McCartt et al., 2009). For this reason, a composite score for age and driving experience was created by converting both variables into standard (Z) scores and then summing them to create one age/experience variable. This variable was used as a covariate for all further analyses. Although other significant correlations emerged, they did not approach levels of concern for multicollinearity, and therefore analyses proceeded as planned.

Table 2. *Predictor and Performance Descriptives*

Variables	Overall (*n*=25)		ASD Drivers (*n*=16)		ASD Pre-drivers (*n*=9)		
	M (SD)	Range	*M (SD)*	Range	*M (SD)*	Range	*t*, *F* or χ^2
Predictor variables							
SAD Negative Score	11.12 (7.05)	0-23	9.94 (7.06)	1-23	13.22 (6.92)	0-21	*t*(23) = -1.12, *p*=.27, η_p^2= .05
Average Heart Rate	86.33 (16.03)	58.78-121.89	80.12 (11.88)	60.00-98.20	96.69 (13.98)	76.81-124.14	**t(23) = -3.15, p< .01, η_p^2= .30**
UFOV Total Score (ms)	184.42 (170.95)	61-693	125.91 (51.36)	61-220	288.44 (252.41)	103-693	**t(23) = -2.52, p=.02, η_p^2= .22**
UFOV 1 (ms)	20.58 (11.96)	17-67	17.20 (0.77)	17-20	26.22 (18.79)	17-67	*t*(23) = -1.89, *p*=.07, η_p^2= .14†
UFOV 2 (ms)	54.48 (78.42)	17-313	26.94 (23.19)	17-100	103.44 (114.99)	17-313	**t(23) = -2.61, p=.02, η_p^2= .23**
UFOV 3 (ms)	109.36 (90.81)	27-430	81.56 (38.36)	27-176	158.78 (132.99)	57-430	**t(23) = -2.19, p=.04, η_p^2= .17**
Driving Simulator Outcome variables							
RMS (SD)	0.63 (0.25)	0.24-1.40	0.56 (0.07)	0.24-0.83	0.76 (0.09)	0.48-1.40	*F*(23) = 2.18, *p*=.154, η_p^2= .09
Reaction Time (sec)	1.07 (0.35)	0.65-1.98	1.12 (0.10)	0.65-1.61	0.96 (0.15)	0.70-1.98	*F*(23) = .57, *p*=.46, η_p^2= .03
Standard Deviation of Speed	11.79 (1.63)	8.16-14.93	11.82 (1.61)	8.16-14.21	11.73 (1.77)	8.88-14.93	*F*(23) = 1.31, *p*=.27, η_p^2= .06
Speeding Exceedances (count)	8.68 (3.66)	3-14	9.63 (3.54)	3-14	7.00 (3.43)	3-12	χ^2(2) = 4.95, *p*= .08, η_p^2= .04†
MVCs (count)	1.84 (1.10)	0-4	1.63 (0.89)	0-3	2.22 (1.39)	0-4	χ^2(2) = 2.98, *p*= .23, η_p^2= .002

Note: M= Mean, *SD*= Standard Deviation, SAD= Scale for Apprehensive Driving, RMS= Root Mean Square (standard deviation) of lane position, MVCs= Motor Vehicle Collisions. **Bold**= $p < .05$. † = Marginal significance ($p < .10$). Reaction Time= Average reaction time across 8 hazards. η_p^2= partial eta squared. Age/Experience was included as a covariate for analyses of driving outcome variables.

Bivariate correlations revealed several strong, significant associations between driver group and predictor variables. Being in the pre-driver group was associated with less age/experience (r = 0.703, p < .0001), lower ASD symptom severity (r = -0.551, p < .01), slower processing speed (UFOV total score) (r = 0.456, p = .02), higher average heart rate while driving in the simulator (r = 0.548, p < .01) and greater lane deviations (r = 0.477, p = .02). Higher self-reported driving anxiety was also associated with less deviation in simulated driving speed (r = -0.416, p = .04). Greater age/experience was significantly associated with greater ASD symptom severity (r = 0.753, p < .001), less self-reported driving anxiety (r = -0.407, p = .04), less lane deviation (r = -0.399, p = .048), and fewer simulated MVCs (r = -0.419, p = .04) (See Figure 2 for scatterplots). Table 3 displays intercorrelations among all variables used in analyses.

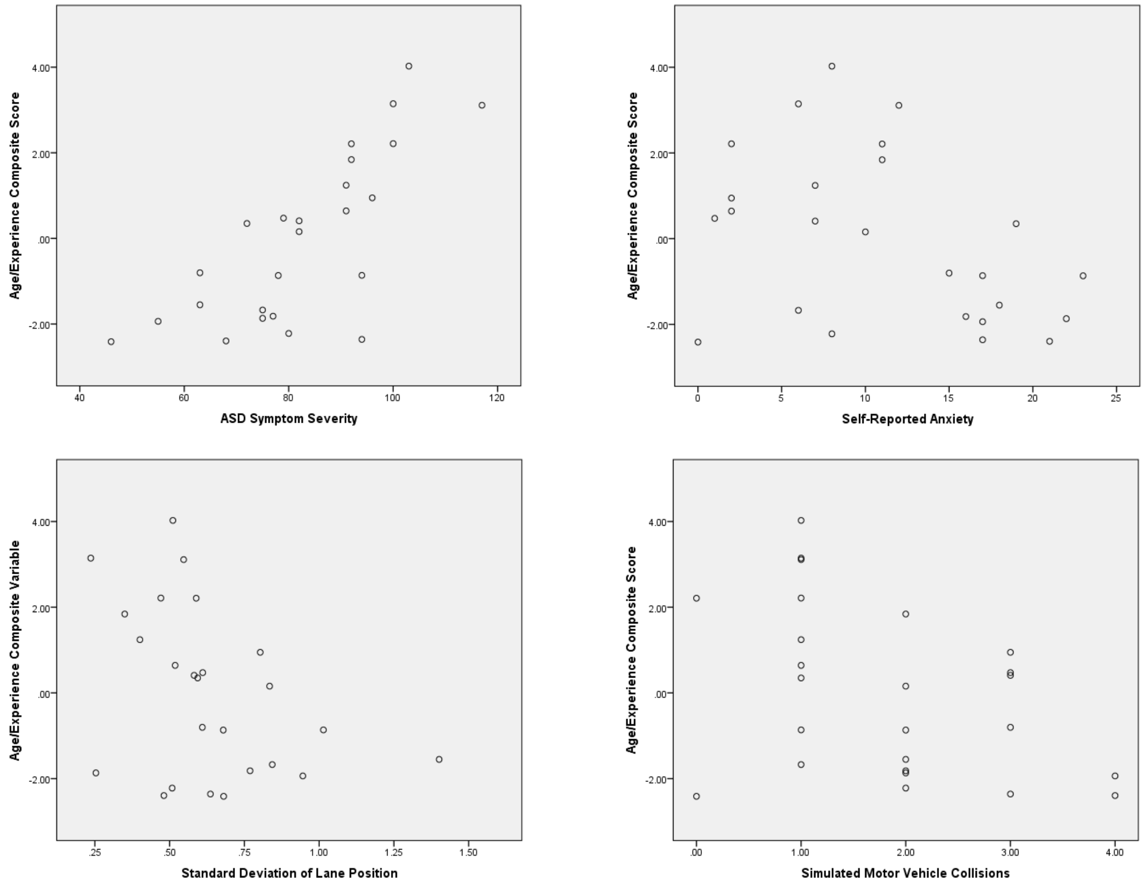

Figure 2. *Intercorrelations with Age/Experience.* Graphs illustrate the correlations between the age/experience variable and: ASD symptom severity (top left), self-reported anxiety (top right), standard deviation of lane position (bottom left) and simulated motor vehicle collisions (bottom right).

Table 3. *Intercorrelations*

	1	2	3	4	5	6	7	8	9	10	11	12
1. Driver Group	1	**-.703****	**-.551****	.261	.228	**.548***	**.466***	**.477***	-.025	-.029	-.351	.265
2. Age/Experience		1	**.753****	-.171	**-.407***	-.343	-.223	**-.399***	-.124	.271	.304	**-.419***
3. AQ Severity Score			1	.026	-.238	-.224	-.330	-.369	-.051	.079	.362	-.298
4. DBRS Total Score				1	.035	-.252	-.063	-.056	-.039	.168	-.010	-.007
5. SAD Score					1	-.020	.276	.185	.141	**-.416***	-.029	.329
6. Average Heart Rate						1	.310	.292	-.241	-.031	-.225	.306
7. UFOV® Total Score							1	.326	-.262	-.002	-.205	.367
8. RMS (SD)								1	-.366	.150	.055	.144
9. Reaction Time (Sec)									1	-.132	-.375	.254
10. SD of Speed (SD)										1	.035	-.261
11. Speeding Exceedances											1	-.219
12. Simulated MVCs												1

Note: Age/Experience= Composite score of age and months since permit was received, RMS= Root Mean Square (standard deviation) of lane position, SD of Speed= Standard Deviation of Speed, MVCs= Motor Vehicle Collisions, Reaction Time= Average reaction time across all 8 hazards, *** *p*<.05, ** *p*<.01**

AIM 1: Compare the driving performance of novice drivers with ASD and experienced drivers with ASD.

All participants were able to demonstrate adequate proficiency in the simulator with 52% of participants passing on the first attempt, 28% of participants passing on the second attempt 20% of participants needing the third attempt to meet the minimum level of proficiency. These rates were significantly different across driver group $t(23) = -2.90$, $p = .008$, with pre-drivers ($M = 2.22$, $SD = 0.83$) needing significantly more attempts to pass the calibration drive than drivers ($M = 1.37$, $SD = 0.62$).

Generalized Linear Model (GLM) with a Poisson distribution analyses covarying for age/experience indicated that there was a marginally significant effect of driver group on number of speed exceedances, with drivers ($M = 9.63$, $SD = 3.54$) having a greater number of speed exceedances compared to pre-drivers ($M = 7.00$, $SD = 3.43$), $\chi^2(2) = 4.95$, $p = .08$. Analyses of Covariance (ANCOVA), controlling for age/experience, revealed no significant difference among drivers and pre-drivers for standard deviation of speed ($F(23) = 1.31$, $p = .27$), RMS ($F(23) = 2.18$, $p = .154$) or reaction time ($F(23) = .57$, $p = .46$). No significant effect of driver group emerged for total number of simulated MVCs ($\chi^2(2) = 2.98$, $p = .23$).

AIM 2: Identify significant predictors of licensure status.

A logistic regression predicting licensure status (pre-driver or driver) for 25 individuals with ASD was conducted. A test of the age/experience model against a constant only model was statistically significant, indicating that the predictor age/experience reliably distinguished between pre-drivers and drivers ($\chi^2(1) = 18.21$, $p < .001$). The Nagelkerke's R^2 was .709 indicating a moderately strong relationship of

70.9% between age/experience and driver group. Prediction success overall for the age/experience model was 84% (87.5% for drivers and 77.8% for pre-drivers). The Wald criterion demonstrated that age/experience made a significant contribution to prediction (p= .014). With each unit decrease in age/experience, an individual was 6.25 less likely to belong to be in the fully licensed group. The addition of subsequent predictors did not significantly improve the model. However, upon closer examination of the model fit, statistics (-2 Log Likelihood) did improve with the inclusion of each of the proposed predictors but not to a level of statistically significance. To explore the potential prediction abilities of the theoretically based predictors and because of the strong association between age/experience and driver group, a second logistic regression was conducted omitting age/experience. A summary of the model statistics for the logistic regression including age/experience as a predictor can be found in Table 4.

Table 4. *Summary of Logistic Regression Including Age/Experience*

	Model 1				Model 2				Model 3			
Variables	*B*	S.E.	*p*	Exp (*B*)	*B*	S.E.	*p*	Exp (*B*)	*B*	S.E.	*p*	Exp (*B*)
Constant	-2.03	1.14	.073	0.13†	0.49	4.85	.920	1.63	-356.32	37447.62	.992	.00
Age/Experience	-1.85	0.75	.014	0.16*	-1.73	0.77	.025	0.18*	-115.13	10009.62	.991	.00
ASD Symptom Severity					-0.32	0.06	.598	0.97	1.78	317.35	.996	5.79
Anxiety Composite Score									-62.36	5560.51	.991	.00
UFOV Total Score (ms)									0.67	78.88	.993	1.96
Observations	25				25				25			
DF	1				2				4			

Note: ***p* < .01, *****p < .05, † = Marginal significance (p < .10). B= Beta coefficient, S.E.= Standard Error.
Maximum iterations were reached for Model 3 indicating no improvement in model fit.

The second, logistic regression was only one step and included: the composite driving anxiety score, ASD symptomology (as measured by AQ symptom severity score) and processing speed (as measured by UFOV total score) as predictors of licensure status. A test of the full model against a constant only model was statistically significant, indicating that the predictors as a set reliably distinguished between pre-drivers and drivers ($\chi^2(3) = 18.34$, $p<.001$). The Nagelkerke's R^2 was .713 indicating a moderately strong relationship of 71.3% between predictors and driver group. Prediction success overall for the full model was 84% (87.5% for drivers and 77.8% for pre-drivers). The Wald criterion demonstrated that both driving anxiety ($p= .070$) and ASD symptom severity ($p= .066$) made a marginally significant contribution to prediction. However, looking at the directionality of the findings, the odds of being in the fully licensed group was 4.5 times higher for every unit increase in anxiety composite score. As ASD symptom severity scores decreased, the odds of belonging to the fully licensed group decreased by 11%. Processing speed was not a significant predictor of licensure status. A summary of the model statistics for the logistic regression excluding age/experience as a predictor can be found in Table 5.

Table 5. *Summary of Logistic Regression Excluding Age/Experience*

	Model 1			
Variables	*B*	S.E.	*p*	Exp (*B*)
Constant	6.38	4.67	.172	586.77
Anxiety Composite Score	1.52	0.84	.070	4.57†
ASD Symptom Severity	-0.12	0.65	.066	0.89†
UFOV Total Score (ms)	0.01	0.01	.216	1.01
Observations		25		
DF		3		

Note: ***p* < .01, ***p* < .05, † = Marginal significance (*p* < .10). B= Beta coefficient, S.E.= Standard Error.

Secondary Analyses

In addition to previously planned analyses, qualitative data was also collected to better understand why participants in the pre-driver group had not yet received their driver's license despite meeting the state's minimum age requirements. Pre-drivers were asked to provide at least one and up to three reasons why they had not yet received their full license. Five general themes emerged when examining participant responses: (1) parental restriction, (2) confidence in driving ability, (3) personal motivation, (4) anxiety and (5) state requirements. All pre-drivers (100%) listed confidence in driving ability as a barrier to obtaining a full license, 11% (*n*= 1) cited parental restriction, 22% (*n*= 2) participants listed personal motivation, 22% (*n*= 2) said that their anxiety has kept them from obtaining a license and 22% (*n*= 2) reported that the only reason they had not yet received a full license is because they had not yet met the state's minimum requirement for "hours of supervised driving practice". Table 6 displays examples of participant responses for each response category.

Table 6. *Self-reported Barriers to Full Licensure*

	Participant Response
Parental Restriction	"My parents don't feel that I'm ready"
Confidence	"Not enough experience" "I don't feel confident about my driving abilities" "I need more practice" "I have safety concerns" "I am not adequately prepared" "I need more experience" "I am not experienced enough yet" "I need more driving training"
Personal Motivation	"I'm too lazy to get one" "I don't really need one yet"
Anxiety	"I get very nervous" "I am nervous a lot"
Legal Restrictions	"I had to have my permit for 6 months" "I need more permit hours"

Note: Data only applicable to pre-driver group.

DISCUSSION

Contrary to original hypotheses, no significant, simulated driving performance decrements were found between pre-drivers and drivers with ASD. Drivers with ASD exhibited a greater number of speed exceedances compared to pre-drivers which may be a result of the greater experience and perhaps confidence among experienced vs. novice drivers with ASD (Lindsay, 2016). Based on a vast body of driving literature on novice, yet typically developing individuals (Braitman, Kirley, McCartt, & Chaudhary, 2008; Crundall & Underwood, 1998), it was expected that novice drivers with ASD would perform significantly worse (greater speed variability, poorer lane position, more simulated MVCs, slower reaction times) on a simulated driving task. This pattern was however not present in the current study's sample of novice and experienced drivers with ASD. Previous research findings have also suggested that the driving performance decrements of individuals with ASD may be minimal or may diminish with increased experience (Bishop et al., 2017). Although non-significant findings should not be interpreted, this finding along with previous mixed finding on ASD and driving performance highlight the need for further investigation into individuals with ASD in the learning to drive phase. As it has been recently suggested by Curry and colleagues (2017) in their large epidemiological study of drivers with ASD, it is likely that there are a group of individuals on the Autism spectrum that have the desire and capability to drive, but are not achieving licensure due to various associated impairments. The absence of decrements in driving performance among the pre-drivers with ASD in the current study may be an illustration of this very point.

Bivariate correlations in the current study were in line with previous literature with membership in the pre-driver group associated with younger age and less driving experience which is consistent with literature on individuals with typical development (Naz & Scott-Parker, 2017). Contrary to expectations based on previous literature, being the in the pre-driver group was associated with lower ASD symptom severity which may have been a result of the high functioning nature of the sample. It may also have been due to the heterogeneous nature of the study groups. For example, the pre-drivers in the current study may have just been on a delayed, but otherwise typical learning-to-drive timeline, while some individuals in the driver group may have obtained a full license and drive only intermittently. Consistent with the development of processing speed which is still developing through adolescence, being in the pre-driver group was associated with slower processing speed (Kail, 1993). Also consistent with previous literature, greater physiological anxiety and greater lane deviation while driving in the simulator was also associated with being in the pre-driver group (Lee, Simons-Morton, Klauer, Ouimet, & Dingus, 2011; Taylor et al., 2008). Greater age and experience was significantly associated with less self-reported driving anxiety, less lane deviation, and fewer simulated MVCs which aligns closely with the large body of literature on the impact of age and experience on driving performance and driving anxiety (Klauer et al., 2014; McCartt, Shabanovaq, & Leaf, 2003; Taylor et al., 2008). In line with the expected findings of the current study, higher self-reported driving anxiety was significantly associated with less deviation in simulated driving speed which may suggest that driving anxiety propagates compensatory driving safety mechanisms to alleviate anxious thoughts (Kontogiannis, 2006).

Drivers with ASD also self-reported significantly greater ASD symptom severity compared to pre-drivers. This was contrary to initial hypothesis and previous research suggesting that individuals who are higher functioning generally report and exhibit less severe ASD characteristics (Zimmerman, Ownsworth, O'Donovan, Roberts, & Gullo, 2016), and these higher functioning individuals are those most likely to drive (Huang et al., 2012). This finding may also speak to the heterogeneity of ASD and may suggest that there were unique groups of individuals within the two groups of the current study. For example, within the group of pre-drivers, there may have been individuals who were on a slightly delayed but otherwise typical timeline for learning to drive (i.e., learner’s permit obtained at 15 and driver’s licenses obtained approximately one year later) and others who had received their learner’s permit and still needed several years of training before obtaining a full license. Interestingly, although pre-drivers self-reported higher driving anxiety (as measured by the SAD) compared to drivers, this difference did not reach statistical significance. However, pre-drivers had significantly higher average heart rate while navigating the simulated driving task indicating that they may have reported lower levels of driving anxiety than they are experiencing during the driving task. Previous literature on the validity of self-report in the ASD population is limited and somewhat mixed with some studies suggesting caution in interpreting self-report measure in the ASD population when examining psychiatric comorbidities such as depression and anxiety (Hughes et al., 1994) and others that suggest that individuals with ASD can accurately self-report emotional states and ASD symptomology (Kelleher, 2013). The findings of the current study align more closely with the former and indicate that self-reporting of psychological anxiety symptoms may be underestimated in the ASD population.

Consistent with hypotheses, pre-drivers with ASD had significantly slower visual processing speed compared to drivers with ASD. This finding is consistent with previous literature on the developmental trajectory of processing speed suggesting that processing speed improves throughout childhood and adolescence, peaking in young adulthood (Kail, 1993). Visual processing speed is an important aspect of driving safety and has been shown to be a significant predictor of simulated MVCs among young drivers (McManus, Cox, Vance, & Stavrinos, 2015). The ability to quickly gather and process information in the driving environment and formulate an appropriate response is a skill commonly cited as a challenge by both parents and their teens with ASD who are learning to drive (Almberg et al., 2015; Lindsay, 2016). Although it was suspected that this cognitive ability was in part, responsible for the lack of licensure in the pre-driver group, findings of the logistic regression did not indicate visual processing speed as a predictor of licensure status.

Findings revealed that only age/experience emerged as a significant predictor of licensure status with higher age/experience predicting membership in the fully licensed group. This is not surprising as two of the main factors involved in the parent/teen decision getting a driver's license are the legal age requirement and hours of supervised driver training. This was also surprising as all of the participants in the pre-driver group met that age requirements for obtaining a full driver's license in the state of Alabama, but had not yet obtained a full license suggesting there were factors other than age keeping them from getting their full license. It was likely an issue of sample size/power that the other hypothesized predictors did not significant improve prediction over and above age and experience. These suspicions were further confirmed when the second logistic regression model was run without age and experience. In this model, driving anxiety and ASD symptom severity emerged as marginally significant predictors of licensure status. However, contrary to expected findings, increases in driving anxiety were associated with membership to the fully licensed group rather than the pre-driver group. Future studies utilizing larger sample sizes should further examine anxiety as a barrier to licensure. Also contrary to hypothesized results, a decrease in ASD symptom severity was associated with decreased odds of belonging to the driver group. This unexpected finding was likely due to the significantly higher ASD symptom severity scores among drivers with ASD in the current study sample.

Strengths

This study has several strengths in comparison to other research studies in the field of ASD and driving. The current study was the first to examine two groups of individuals with ASD: those with only a learner's permit and those who were fully licensed. There is a growing need to investigate and better understand the learning to drive process in individuals with ASD. For example, the findings of the current study suggest that the pre-drivers with ASD were capable of navigating the driving environment successfully, but had not yet received their full license yet for reasons other than the legal age requirement. Not only was the current study the first to compare individuals with ASD at different stages of licensure, it was also the first to investigate driving anxiety specifically as a barrier to licensure. General anxiety is an extremely common issue in the ASD population (Gillot et al., 2001), so it stands to reason that the complex and daunting task of driving which cause anxiety in typically developing teens, would pose a challenge for individuals on the Autism spectrum. A driving simulator was also used in the current study, which allows for the investigation of driving behavior in an at-risk population of drivers in a safe and ethical environment. Much of the knowledge in the research community on ASD and driving is based on survey and caregiver data (Lindsay, 2016), which may not provide the most complete picture drivers with ASD. The current study objectively assessed driving performance through the use of driving simulator, which will certainly add to the body of survey data.

The current study improved upon previous study designs in several ways. Much of the work done in the area of ASD and driving is done in a population of individuals with cognitive impairment who may never drive independently (Sheppard et al., 2010). Other studies have examined only individuals who had already obtained a full driver's license, which does not capture the challenges facing individuals who are still in the learning to drive phase (Bishop et al., 2017; Lindsay, 2016). The current study was unique in its design to examine and compare a group of individuals with ASD who had received a learner's permit and were planning to drive independently and a group of individuals with ASD who had successfully obtained a driver's license. Further, the current study also collected data regarding participants' driving experience (i.e., months since learner's permit was received), which allowed us to control for the differences between the groups on age and experience and isolated psychological and cognitive differences.

Limitations

Every research study has limitations, and the current study is no exception. The sample of the current study is one area of weakness for the current study. As is the case with many studies utilizing clinical populations, the sample size of the current study was small. It should be noted however that the sample size of the current study is comparable to other driving simulator studies in the research area of ASD and driving (Sheppard, van Loon, Underwood, & Ropar, 2016). With a larger sample size, several of the marginal findings of the current study may have approached statistical significance, however future research is needed to further investigate these trends. A larger sample size may also have allowed for greater statistical power to detect significant predictors of licensure status.

Another challenge of working with a population of individuals with ASD is the heterogeneous nature of the disorder (Masi, DeMayo, Glozier, & Guastella, 2017). It was the current study's goal to compare two group individuals with ASD: those who had thus far only been able to obtain a learner's permit and those who had reached independent licensure status. It may be however that within the two groups, there was a great deal of variability in wiliness, motivation and ability to drive. Because of the heterogeneous nature of ASD's, it is also difficult to generalize findings to the entire population of individuals with ASD. Due to the complex nature of the driving environment and the high level of motor coordination and processing speed required to navigate the driving environment effectively, it is likely that findings of the current study are only applicable to individuals on the high-functioning end of the Autism spectrum.

Further, the current study utilized self-report as both confirmation of ASD diagnosis (self-report of previous diagnosis) and as a measure of ASD symptom severity

(AQ severity score). Previous research has suggested that there may be concerns related to the accuracy of self-reported autistic symptomology using the AQ and its accuracy in differentiating between individuals with ASD from other clinical populations (Naito et al., 2010a). There are however several studies that note its usefulness in quickly assessing and categorizing individuals with ASD (Baron-Cohen et al., 2001; Hurst et al., 2007; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). It would be beneficial for future driving studies to include more objective, clinical measures of ASD symptomology such as the Autism Diagnostic Observation Schedule (ADOS) or Autism Diagnositc Interview, Revised (ADIR) (Mazefsky & Oswald, 2006).

One possible improvement on the current study is in regards to the collection of heart rate data. Although previous literature has used average heart rate as an indicator of physiological anxiety, a more precise measure of physiological anxiety such as R-R intervals, RMSSD and/or galvanic skin response may potentially provide a more complete picture of physiological anxiety while driving through the simulator (Gorman & Sloan, 2000).

Future Directions

ASD is growing increasingly more prevalent and it is estimated that in the next year nearly 75% of individuals diagnosed with ASD will be 19 years or older (Centers for Disease Control and Prevention [CDC], 2015a). Driving is a major component to a successful transition into adulthood, finding and maintaining employment and fostering positive social experiences (Curry et al., 2017). More research is needed to fully understand the transportation and safety needs of this constantly growing population. It is suspected that the eligibility and exclusion criteria of the study limited the sample of participants to only those individuals with ASD who had the highest likelihood of successfully becoming independent drivers (i.e., those who were driving and those who had already obtained a learner's permit). In this way, we may not have captured a subset of individuals who were thinking about driving, but had not yet begun the learning to drive process (i.e, no learner's permit). As has been suggested in previous work, families of individuals with ASD often make the decision to drive before the learning to drive phase is begun and of individuals who pass the learner's permit examine, the majority go on to receive their full license (Curry et al., 2017). Future research would benefit from investigating the various subgroups of pre-drivers and drivers with ASD to better serve the population and increase independent driving rates. As driving anxiety is a commonly reported issue for individuals with ASD, virtual reality technologies should be investigated as mechanisms for reducing driving anxiety. Previous research has shown promising findings with regard to the impact of virtual reality in anxiety reduction (Masi et al., 2017). Driving simulators may serve as an excellent tool for the reduction of driving anxiety specifically as it allows individuals to experience and interact with risky, anxiety-provoking driving situations in a safe and ethical way. Individuals with ASD may also benefit greatly from the implementation of proven, therapeutic techniques to specifically target driving anxiety such as cognitive behavior therapy (CBT) (Bruggink, Huisman, Vuijk, Kraaij, & Garnefski, 2016). Not only has previous research demonstrated the usefulness of virtual reality in reducing anxiety symptoms, virtual reality driving environments have also shown promise in training and improving driving performance in novice drivers with ASD .

Future research should also aim to identify unique groups within the population of individuals with ASD who are thinking about or are currently in the learning to drive process. Based on the findings of the current study and recently conducted survey data, it is suspected that there may be significant differences within the category of pre-drivers with ASD with regard to motivation, parental restriction, anxiety and driving experience. Further, there may also be different groups within the population of drivers with ASD (i.e., individuals who drive only when necessary, individuals who do not drive). Further within these groups, individuals with specific patterns of cognitive impairments should be investigated to determine if driving challenges are related to ASD symptomology, or cognitive impairments commonly associated with the disorder (i.e., executive dysfuction, attentional issues, impaired processing speed). These individuals all required different levels of support with regard to transportation. These specific needs should be identified and interventions should be designed to meet them.

Conclusions

From the findings of the current study, there are various implications for the formation and implementation of driving training programs for those with ASD. As no differences were seen in simulated driving performance for pre-drivers versus drivers with ASD, it may suggest that these individuals have the skills needed to drive successfully, but may be hesitant to move forward due to factors other than age (Chee et al., 2015; Daly et al., 2014). Further research is needed however to identify these factors.

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APPENDIX A

IRB APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on January 24, 2017. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

Principal Investigator:	STAVRINOS, DESPINA
Co-Investigator(s):	JOHNSON, HALEY D
Protocol Number:	**X140820006**
Protocol Title:	*ROADS - Research On Autism and Driving Study (Understanding and Preventing Motor Vehicle Crashes Around Social and Non-Social Hazards Among Adolescent Drivers with Autism Spectrum Disorders)*

The IRB reviewed and approved the above named project on 8-12-15. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 8-12-15

Date IRB Approval Issued: 8-12-15

IRB Approval No Longer Valid On: 8-12-16

HIPAA Waiver Approved?: N/A

Marilyn Doss
Member - Institutional Review Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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