EFFECTS OF MUSIC ON DRIVING PERFORMANCE OF EXPERIENCED DRIVERS WITH AND WITHOUT AUTISM SPECTRUM DISORDER

By

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Rationale: Achieving a driver's license is often essential for teens in order to achieve independence and expand their participation in their community through work and/or further education as well as social participation. Individuals with Autism Spectrum Disorder (ASD) often have difficulty achieving licensure due to difficulties with anxiety, sensory processing issues and impairment in executive functioning. Research also demonstrates that individuals with ASD have more driving performance errors compared to their neurotypical peers. Music is a factor that can affect driving performance by diverting attention, causing aggression, and changing perception of time and speed. However, music may mediate some of the psychological challenges those with ASD face, specifically with novice drivers with ASD. **Purpose:** The purpose of this study was to further investigate the effects that self-selected background music has on the driving performance of experienced drivers with ASD compared to experienced neurotypical drivers. **Design:** A 2 (autism/neurotypical) x 2 (music/no music) x 2 (hazards/wayfinding) factorial design was used. **Methods:** Participants included 34 neurotypical adults and 5 adults with ASD who were experienced drivers. All participants completed a driving history questionnaire and sensory profile before completing four different driving scenarios (two hazard and two wayfinding) on the driving simulator. During two of the drives the participant listened to self-selected music. The order the participant completed the drives/music was counterbalanced to prevent learning effects. The dependent variable of driving performance was measured by the Performance Analysis of Driving Ability (P-Drive), both the total and four subcategories. **Results:** Repeated measures ANOVA showed no significant difference in driving performance on the total scores between music condition ($p = 0.760$), however there was a significant difference between drive ($p=0.001$) and group ($p=0.049$) indicating that drivers with ASD had higher driving performance scores than their neurotypical counterparts. No significant interaction effects were found. **Conclusion**: Results of this study indicate that music does not significantly affect driving performance either positively or negatively, contradicting previous studies. However, most studies have been done with novice drivers, thus it may be that experience makes a difference. In addition, the higher performance of the drivers with ASD suggest that experience improves performance so that drivers with ASD may be better drivers than neurotypical drivers as they are more likely to drive following speed limitations.

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Introduction

Occupational therapy is the therapeutic use of everyday activities to enable participation. Occupational therapists assist clients in regaining their independence so they can participate in the activities that they find important. One category of occupations is instrumental activities of daily living (IADLs) or activities we do in our daily life that require complex interactions. Driving and community mobility is one IADL (American Occupational Therapy Association, [AOTA], 2014). Being able to participate in driving and community mobility helps enable participation in roles, habits, and routines (AOTA, 2014). Community mobility is essential for independence as it enables an individual to have access to engagement in their daily activities. Driving specifically contributes to our health and quality of life because it allows independence, gives us a sense of identity, and allows us to participate in social environments. Losing the ability to drive can create feels of loneliness, isolation, and other depressive symptoms (Stav, Pierce, & DeLany, 2010).

Driving is a goal-directed complex activity that requires multitasking and smooth alternation of different tasks (Ross et al., 2018). Skills required to drive are typically learned in adolescence or young adulthood and include motor control, cognitive processing, being able to adapt to changing environments, and having control over emotions and behaviors (Ross et al., 2018). Neurotypical individuals normally develop these skills in everyday activities as they develop. However, individuals with developmental disorders may have difficulty developing or learning these skills.

Autism Spectrum Disorder (ASD), one of the most common neurodevelopmental disorders, is characterized by impairments in social interaction, communication, and the presence of repetitive behaviors (Masi et al., 2017; Suarez & Ellsworth, 2017). As an individual with higher functioning ASD ages and transitions into adulthood they are expected to become part of their community by participating in different experiences regardless of their disability (Ross et al., 2018). In order to participate in these experiences, they need a means of community mobility. Driving is the typical option for people, however, individuals with ASD are reported to drive less frequently. Curry et al. (2017) found that by the age of 21, only 33.3% of adolescents with ASD had a driver's license, compared to the 83.5% of neurotypical adolescents that had their license (Curry et al., 2017). If they don't have their license, individuals with ASD often depend on their friends and family to drive them around (Ross et al., 2015). While characteristics of ASD vary per person, some of the characteristics they can have can negatively affect their driving ability. Visual information processing deficits and limitations in planning and executing actions in response to changes can limit their driving ability (Ross et al., 2015). However, even though individuals with ASD have these deficits, they also can have some characteristics to help them be better drivers compared to their neurotypical peers. Ross et al. (2015) found that ASD drivers can follow traffic rules more strictly and can have more cautious driving styles. These characteristics can lead to fewer crashes compared to their neurotypical peers (Ross et al., 2015). To help increase the number of ASD drivers, there is a need for research on tools and strategies ASD drivers can use to help them drive safer. Music could potentially be a strategy.

Music serves many purposes in people's lives, such as a way to manage mood, as background noise, as something to sing along with, as something used to reflect on the past or to enjoy the present, as a social interaction tool, or as a distraction (Lonsdale & North, 2011). The purpose of music can be different depending on what genre of music the person is listening to. A study by North, Hargreaves, and Hargreaves (2004) found that those who listened to pop music listened to it because it helped them concentrate (13.4%), helped pass the time (45.3%), created the right atmosphere (28.8%), and because they enjoyed it (49.7%).

Music is also now more easily accessible, meaning people can listen to music in many different contexts. In the same study, North et al. (2004) found the most popular place to listen to music was in the home (50.1%) with the second most popular place was while driving (11.8%). They found purposes of music while driving also varied: concentration (19.6%), pass the time (51.1%), create emotions (13.9%), and habit (47.7%) (North et al., 2004). Because of the increasing trend of listening to music in cars, research needs to be done on the effect music can have on drivers.

Listening to music while driving is a common activity and will very likely remain so. However, there is potential for music while driving to be a distraction for any teen driver, but it is possible that teens with ASD may be more at risk than their neurotypical peers. It is also possible that, for some teens, music may be a modifier for distracted behaviors. Thus, the effect of music needs to be investigated with both neurotypical drivers and drivers who have autism. This study will explore how different types of music will impact the complex task of driving.

Literature Review

Autism Spectrum Disorder

Autism spectrum disorders (ASD) include a continuum of disorders characterized by varying degrees of impairments in social interaction, communication, and the presence of repetitive behaviors (Masi et al., 2017; Suarez & Ellsworth, 2017). The move to the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5) expanded the definition of Autism Spectrum Disorder to combine Autistic Disorder, Asperger's Syndrome, and Pervasive Developmental Disorder-Not Otherwise Specified into one (Masi et al., 2017). There is no definitive cause for ASD, however, researchers believe that it is a combination of genetics and environment (Suarez & Ellsworth, 2017).

The prevalence of autism is 1 in 68 - a number that has been increasing over the years. While some individuals with autism have severe impairments, individuals with high functioning autism's (HFASD) main symptoms include difficulty in social interaction and the occurrence of restrictive and repetitive behaviors with other common characteristics that include food selectivity, fine and gross motor impairment, and sensory processing problems (American Psychiatric Association, 2013). In addition to these characteristics, executive functioning deficits are a common cognitive deficit linked with autism (Suarez & Ellsworth, 2017). Executive functioning is used to describe problem-solving behaviors and includes forming abstract concepts, focusing and sustaining attention, retrieving relevant information quickly, being able to self-correct, and being able to prevent impulsive responses (Liss et al., 2001). Individuals with high-functioning autism typically have deficits in executive functioning, emotional perception, and verbal memory (Ozonoff et al., 1991). In fact, with many HFASD, deficits in executive functioning are typically the hallmark (Barkley, 2012).

Another major component of ASD is sensory processing and environments. Individuals with ASD can be either hyper or hyporeactive to different sensory inputs (Masi et al., 2017). They may also have an unusual interest in certain sensory aspects in their environment. Depending on the environment, symptoms of autism can be exacerbated or calmed. When the environmental demands are more than the individual's functional capacity, the symptoms can get more severe (Masi et al., 2017).

Abilities Required to Drive

Driving requires many different skills to work all at the same time. It requires social judgement, pre-planning, motor coordination, prioritizing, the ability to focus, the flexibility to change, and the ability to control one's anxiety and sensory activities (The Children's Hospital of Philadelphia Research Institute, 2020). Based on Michon's 1985 hierarchy of driving behaviors (e.g., strategical, tactical, and operational), a revised model of how to conceptualize driving has been established (Transportation Research Board [TRB], 2016). The strategical level is the planning level. Drivers determine the goals and route of the drive and evaluate the costs and risks involved. When encountering a crash or construction, skills at the strategic level allows an individual to adapt their plans, make unexpected stops, change their trip goal, or seek help if lost. The tactical level is the maneuvering level. This level allows drivers to negotiate driving scenarios that are learned and practiced such as obstacle avoidance, gap acceptance, turning, and overtaking. These maneuvers must meet the predetermined criteria developed in the strategical level. Finally, the operational level is the control level. This level involves automatic action patterns that occur in milliseconds. Physically steering the wheel, shifting gears, pressing the pedals, and using turn signals occur at this level and typically become automatic with practice (Dickerson et al., 2018; Michon, 1985).

Many performance skills are needed to be able to drive successfully. As Dickerson and Niewoehner (2012) describe, an individual's motor and praxis skills have to be sequenced and organized as part of the driving plan. In addition, certain movements, such as moving between pedals and using the steering wheel, need to be automatic and quick, require dexterity, and rely on procedural memory. However, the individual has to be able to scan their environment, make judgements, and execute actions. They also have to be able to use visual-perceptual skills to locate, identify, organize, interpret, remember, and respond to their environment. In addition, drivers must be able to regulate their emotions so that they do not interfere with their driving (Dickerson & Niewoehner, 2012).

Adequate visual skills are also essential to safely drive. Visual acuity, the ability to see details, is tested before one is able to get their driver's license. Elgin et al. (2012) describe how good visual acuity is needed to be able to see road signs and other driving details at a safe distance. Peripheral vision is needed to prevent driving collisions and maintain safety awareness. Contrast sensitivity, or the ability to see light-dark transitions, allows an individual to see patterns and objects in their environment. Deficits to this skill leads to increased crashes (Elgin et al., 2012).

Most importantly, driving requires functioning cognitive skills in order to be successful. Barco et al. (2012) describe three components of cognition required for driving: attention, memory, and executive functioning, although processing speed and visual-perceptual abilities are also important. Four types of attention – selective, sustained, alternating, and divided– are required in driving. Selective attention allows an individual to focus on the important aspects of driving and ignoring irrelevant information. Sustained attention is the ability to maintain attention over a long period of time and alternating attention allows an individual to shift between different stimuli. Finally, divided attention is the ability to attend to two more tasks at the same time (Barco et al., 2012).

Visual memory and procedural memory are used heavily while driving. Visual memory allows an individual to remember routes and directions, and procedural memory allows an individual to remember how to put the key in the ignition, which pedal does what, and how to change gears. Executive functioning helps control information processing and is used in decision making while driving (Barco et al., 2012).

Barco et al. (2012) also describes the visual-perception domains used in driving. Depth perception, spatial relations, right-left discrimination, topographical orientation, and figure ground-discrimination are all required to drive. Depth perception and spatial relations allow an individual to correctly perceive gap and stop distances. Right-left discrimination aids with following directions to a specified location. Topographical orientation helps an individual not get lost or confused in a parking lot, and figure-ground discrimination allows a pedestrian to stand out from the background. The speed that new information is integrated and retrieved from memory is processing speed. An individual needs functioning processing speed so they can identify stimuli in the environment and react to unexpected hazards (Barco et al., 2012).

Autism and Driving

The Children's Hospital of Philadelphia Research Institute (2020) found that one in three young adults with autism spectrum disorder earned a driver's license; they just did so on a delayed schedule (The Children's Hospital of Philadelphia Research Institute, 2020). However, since driving is a complex IADL, the deficits frequently seen with ASD, even high functioning ASD, may be more evident when performing the task of driving. For example, Classen, Monahan, and Wang (2013) did a study using a STISM simulator integrated into a Dodge Neon car cab. Teenage ADHD and ASD participants (22) and healthy control teens (22) completed the simulated drive. They found that the ADHD/ASD participants had more motor performance deficits and postural instability. They prioritized information ineffectively and had delays in attention shifting to perceive the many stimuli on the road. They also performed worse on planning, attention, set shifting, and sequencing compared to the healthy controls. Overall, the ADHD/ASD participants made more driving performance errors on the simulator. It is important to note that the data collection tool of the simulator did not indicate a difference in driving errors between the two groups, but the driving rehabilitation specialist *observed* more errors in the ASD group. (Classen, Monahan, & Wang, 2013).

In a similar study, Classen, Monahan, and Hernandez (2013) had seven ASD participants and 22 healthy controls complete a STISM simulated drive to assess seven driving errors – lane maintenance, speed regulation, gap acceptance, adjustment to stimuli, visual scanning, vehicle positioning, and signaling. They found the ASD group performed worse on all the simulator operational skills. They made significantly more errors in visual scanning, lane maintenance, speed regulation, signaling, and adjusting to stimuli. They also had more traffic light tickets compared to the healthy control (Classen, Monahan, & Hernandez, 2013).

Research on licensure rates for drivers with autism is limited. Curry et al., (2018) added to the limited knowledge base by conducting a retrospective cohort study on 52,172 New Jersey residents. Out of the 297 parents of individuals with ASD in their study who were in driving age, 63% reported that they were driving or planning on driving. Most of the teens with ASD who had a learner's permit continued to become licensed drivers. Their research shows that driving is an important issue for many families with ASD (Curry et al., 2018).

All these studies suggest that individuals with autism may have difficulties learning to drive, but it is possible with appropriate support. They do want to learn how to drive, but they do have many to face many difficulties. Some drivers with Autism struggle with prioritizing information and attention, lane maintenance, speed regulation, and signaling ((Classen, Monahan, & Hernandez, 2013). However, more than half of individuals with autism in the driving age range are driving or plan on driving and most who have their learner's permit continue to get their license (Curry et al., 2018).

Music and Performance

Music in the Classroom and Workplace

People are affected by listening to music in many areas of life. Research into music in the classrooms has found interesting results. An et al. (2013) investigated if having music integrated into math classes could improve math skills. Participants include 25 third graders and 21 first graders had math class with integrated music components. Examples of music integration include musical instruments, music-based math manipulatives, and actual music pieces. Results showed that music helped the students with addition/subtraction fluency and solving word problems. They also found increased abilities in the student's abilities to draw pictures, tables, or charts and use math symbols, equations, and inequalities to solve word problems. The researchers hypothesized that listening to music helped the participants make more connections in the different math domains (An et al., 2013).

In an earlier study, Hallam et al. (2002) looked at how music can affect performance on memory tasks. Participants (30 children) were randomly divided into three groups: a control group, a quiet calm music group, and an exciting, aggressive music group. Children in each group completed a memory task where they had to remember specific words in sentences. They found that the calm, relaxing music had a positive impact on the number of words the children remembered while the exciting, aggressive music had a negative effect on their memory performance. Their results show a link between the effects of music on task performance and the effects on the individual's arousal and mood (Hallam et al., 2002).

Finally, music appears to be helpful in the workplace. Lesiuk (2005) researched the effect of music on positive mood, work quality, and time on task. Data was collected on 56 employees when they did and did not listen to music as they were working. The researcher found that music could improve the participant's mood at work. She proposed that this increase in mood could create positive feelings about work which could then increase performance on work-related tasks. During the week when music was not allowed to be listened to, the lowest quality of work scores was reported. Also, when there was no music, it took the participants longer to complete tasks compared to when music was playing (Lesiuk, 2005).

Music and Driving

Driving alone has been reported to be the most frequent place to listen to music (Brodsky, 2001). In fact, Dibben and Williamson (2007) found it to be the most preferred in-vehicle activity. While they are listening, people often sing which helps become actively engaged to help minimize boredom. Singing can also help driving performance by increasing positive mood and arousal (Dibben & Williamson, 2007). Some people prefer music over conversation because it is less distracting (Dibben & Williamson, 2007).

There are many different types of music to choose to listen to in the car; however, some may be more arousing than others. In a 2001 study, Brodsky found that the level of arousal you feel toward a particular song depends partially on the temperament of the listener and the circumstances of where you listen to it. Dibben and Williamson (2007) have shown that even when drivers perceive benefits to listening to music, it can still serve as a potential distraction. Thus, this suggests the kind of music you listen to in the car can determine what kind of changes you will make while driving. Arousing music has been found to be more cognitively demanding on the driver (Brodsky, 2001). Fast music can divert the driver's attention away from the road and can cause more aggression (Dibben & Williamson, 2007). For example, electronic and dance music were associated with an increased number of accidents in younger drivers (Dibben & Williamson, 2007).

The tempo of music can also affect individuals. Brodsky (2001) compared driving performance with music with fast and slow tempos. When participants listened to songs with slower tempos, they perceived time and speed as slower than it actually was. However, when the tempo of the song was increased, their perceived and simulated driving speed increased (Brodsky, 2001). In addition to affected speed, music tempo can also affect traffic violations. In the same study, Brodsky (2001) had twenty participants use a driving simulator. Each participant went through four driving conditions: no music, slow tempo music, medium tempo music, and fast-tempo music. As the participants went through the simulated conditions, the researcher manually recorded the frequency of virtual traffic violations. While no main effects were found for collisions and lane crossings, Brodsky did find a trend – as the music tempo increased, the frequency of collisions increased. In addition, a significant main effect for tempo was found with disregarded red traffic lights. Results found that 20% of the participants disregarded red traffic lights an average of 2.5 times when no music was heard, 35% disregarded an average of 1.6 red-lights with slow music, 45% disregarded an average of 1.2 red-lights with medium music, and 55% disregarded an average of 1.8 red-lights with fast-pasted music. Brodsky's (2001) results showed faster tempos resulted in more vehicular collisions, lane crossings, and ignored red traffic lights in the virtual driving experience compared to slower tempos (Brodsky, 2001)

Self-Selecting Music on Performance

Who selects the music can also affect the people differently (Cassidy & MacDonald, 2009; Lesjuk, 2010; Lingham & Theorell, 2009). Cassidy and MacDonald (2009) took a "listener-centered" approach to compare driving performance with self-selected and experimenter-selected music. Participants used virtual driving experience to complete three laps in one of five different sound conditions: silence, car sounds only, car sounds with self-selected music, car sound with high-arousal experimenter selected music, or car sounds with low-arousal experimenter selected music. The researchers measured the number of collisions, time, and speed, in addition to perceived enjoyment, distraction from the task, liking of the music, and appropriateness of the musical stimulus for the task. Results showed when participants selected their own music, they were more efficient, had lower distraction, higher enjoyment, and had significantly reduced tension-anxiety. Participants performed the worst when they listened to experimenter-selected high arousal music as they made more collisions, had shorter lap times, and drove faster. They had more inaccuracies, higher distraction, lower enjoyment, and had a significant increase in tension-anxiety. A strong negative correlation between an individual's perceived liking of the music and their inaccuracies was found. The greater the perceived enjoyment, the fewer inaccuracies made (Cassidy & MacDonald, 2009).

Self-selected music may improve mood and lower stress. Lesiuk (2010) found when participants listened to their own self-selected music, they were more relaxed and more focused on their tasks. Participants at a technology company (N=24) went through two different music conditions (music and no music). When in the music condition, participants were allowed to listen to their preferred music whenever they wanted to. Their state of positive affect, negative affect, and cognitive performance was measured throughout the different conditions. Results indicated a statistically significant improvement in both mood and cognitive performance scores (Lesiuk, 2010).

Another study had participants self-select stimulatory and sedative music to compare the effects (Lingham & Theorell, 2009). Questionnaires assessing stimulatory emotions and sedative emotions were given both before and after each music condition. Self-selected stimulatory music significantly increased joyful, elated, and energetic moods. Self-selected sedative music also significantly increased feelings of energy and joy, however, it also significantly increased feelings of calmness and relaxation. Heart rate increased significantly when self-selected stimulating music was played indicating higher arousal (Lingham & Theorell, 2009).

Autism and Music

Studies (Burleson, Center, & Reeves, 1989; Hallam & Price, 1998; Lundqvist, Anderson, & Viding, 2009; Hillier, Greher, Poto, & Dougherty, 2012) have found that children with autism are especially sensitive and attentive to music. For example, Burleson et al. (1989) hypothesized that for children with autism, music can increase task accuracy and decrease off-task responses. In this study, they measured the accuracy in a five-minute color sorting task. During the baseline phases, no music was played in the background, and in the intervention phases instrumental music was played in the background as the participants sorted. Results supported their hypothesis, as all participants had 60% or greater improvement in accuracy (Burleson, Center, & Reeves, 1989).

Music can also improve psychological outcomes. Hillier et al. (2012) created a pilot music program for young adults with autism spectrum disorder. "SoundScape", their eight-week program, included 13-29-year-old participants coming into 90-minute weekly music sessions. During the sessions, music education and psychology students and faculty-led the participants in different hands-on music-making activities. During the program, the participants created short films with a music soundtrack in groups to promote social interactions. They found music participation affected the psychological challenges often associated with individuals with ASD. Specifically, music could significantly decrease anxiety, increase self-esteem, and improve attitude toward peers (Hillier, Greher, Poto, & Dougherty, 2012).

Having music playing in the background may also help some individuals with autism in the classroom. Hallam and Price (1998) found that playing “mood calming” music as background music in a classroom can help students who have anger/disruptive behavior issues become calmer and more co-operative. They became less stressed, more relaxed and more productive. It also helped emotionally and behaviorally disturbed children perform better on math tasks (Hallam & Price, 1998).

Music can also help with reducing some of the negative behaviors associated with autism. Lundqvist et al. (2009) found that vibroacoustic music (playing music with specially designed speakers designed to have the individual hear and physically feel the music) can reduce self-injurious, stereotypic, and aggressive behaviors in individuals with developmental disorders. There are specific frequencies or sound combinations that when played, can help calm individuals with autistic. The familiarity of the music can also influence the effect. They found that being familiar with the music can increase a sense of security (Lundqvist et al., 2009).

These studies show that music, as sensory input, can affect all individuals, but particularly those individuals with ASD. Music can help increase task accuracy and decrease incorrect behaviors as well as decrease angry and disruptive behaviors. In addition, it can also reduce self-injurious and stereotypic behaviors. Thus, there is strong support for using music when working with individuals with ASD.

Autism, Music, and Driving

There is limited research on the combination of autism, music, and driving. A study by Goehmann (2018) compared music effects on driving a simulator with a group of ASD participants and a group of neurotypical participants. Participants with ASD (18) and neurotypical participants (15) completed three driving scenarios on the driving simulator. For each scenario there was a different music condition: no music, light classical music, or self-selected background music. As the individuals completed their drives, they were measured using a standardized observational driving evaluation (Goehmann, 2018).

Goehmann found that background music did not affect driving performance which provides evidence against the common assumption that music is a distraction while driving. When comparing the different music conditions, no significant pattern emerged between the three groups (no music, self-selected, classical). No significant differences between self-selected fast tempo music and slower music were found. However, when participants drove in the classical music condition, participants performed better in measures of yielding, stopping, and following speed regulations. In the no-music condition, participants performed better in measures of the number of times off the road and percent of time out of lane which suggests that listening to no music while driving can lead to better lane positioning while on the road, but these differences in both conditions were not significant (Goehmann, 2018).

Surprisingly, when comparing the ASD group with the neurotypical group, Goehmann (2018) did not find any overall differences in driving performance. This suggests that ASD drivers can drive on the driving simulator just as well as their neurotypical peers, especially if you assume that performance on driving simulators is representative of performance on the road (Shechtman et al., 2009). However, examining the ASD group alone, there were significant differences between music conditions. Specifically, performance in the self-selected music condition was better than the other music conditions. This supports the idea that specific auditory sensory strategies can be used to create an optimal environment for an ASD driver (Goehmann, 2018). More research needs to be done to figure out possibilities for why these results occurred.

Summary

Independent research is available on autism, music, and driving, however there is a gap in the research on all three together. It is clear that music can help those with autism and can help typically developing drivers when used appropriately, but it is still unclear how music can help those with autism when they drive. Historically, driving independently is much less common for individuals with ASD compared to those without ASD. Thus, being able to find new ways to help individuals with ASD gain this independence is of utmost importance. The purpose of this study is to extend the Goehmann (2018) study by investigating the effects of different kinds of background music on more experienced drivers with autism and neurotypical drivers with different driving conditions. There will be three main research questions (main effects):

1. Is there a significant difference in driving performance on an interactive driving simulator between experienced drivers with ASD and experienced drivers who are neurotypical?
2. Is there a significant difference in driving performance on an interactive driving simulator when driving with or without music?

3. Is there a significant difference in driving performance on an interactive driving simulator between a drive with hazards and a wayfinding drive (an exploratory question)?

There will also be an examination of interaction effects between the three independent variables: type of driver, different music conditions, and the two driving conditions.

Methods

Design

A 2 (Diagnosis: ASD, Neurotypical) x 2 (Environment: no music, self-selected) x 2 (Scenario types: wayfinding, hazards) factorial design was used to answer the research question in this study. The two groups of participants included individuals with autism spectrum disorder and neurotypical individuals. During each simulation drive each participant listened to two different environmental conditions: no music or self-selected music.

The participants drove under two conditions (wayfinding, hazards). However, to avoid the learning curve, four scenarios were used, two types of wayfinding for the wayfinding condition, and two drives with hazards for the hazard condition. The independent variables in this study are the environment condition (no music, self-selected music), the diagnosis (individuals with ASD, individuals without ASD), and the driving scenarios (hazard, wayfinding), and the dependent variable is the total score based on their driving performance. Driving performance was measured for the participants on the driving simulator using a standardized observational tool to measure performance. The order of the environmental conditions and the order of different driving scenarios were counterbalanced to prevent any order effects (Figure 1). Participants were randomly assigned to one of the four counterbalancing conditions. The city map (visual directions) (Appendix B) was used for one of the wayfinding drives and written directions was used for the other wayfinding drive.

Figure 1: Counterbalancing Driving Scenario and Music Environment

Hazard - no music Wayfinding – no music Hazard – self-selected music Wayfinding – self-selected music	Wayfinding – self-selected music Hazard – self-selected music Wayfinding – no music Hazard - no music
Hazard – self-selected music Wayfinding – self-selected music Hazard - no music Wayfinding – no music	Wayfinding – no music Hazard - no music Wayfinding – self-selected music Hazard – self-selected music

Participants

A power analysis was completed to determine how many participants were needed in this study. Using means and standard deviations from Goehmann's (2018) raw data, to be able to detect differences between music conditions for the ASD group, 19 individuals were needed. To be able to detect differences in the effect of music between the two groups (ASD and Neurotypical) 64 (32 neurotypical individuals and 32 individuals with autism) total participants was considered the ideal number for this study.

Participants were recruited using convenience and snowball sampling methods. Advertisements were sent out to East Carolina University, Pitt Community College, the Autism Society of North Carolina Greenville chapter, and to a local doctor's office. Participants were offered a $40 amazon gift card for participation. Inclusion criteria for the ASD group include a self-reported diagnosis of ASD, a driver's license or permit, and at least 3 years driving experience. Exclusion criteria for the ASD group include any other significant diagnoses. The inclusion criteria for the neurotypical group include having a driver's license and at least three years driving experience. Exclusion criteria for the neurotypical group include any neurological diagnoses or developmental disabilities and vision impairments. Since using the driving simulator can cause simulation sickness in some participants, an exclusion criterion for both the ASD group and neurotypical group includes a history of motion sickness.

All participants signed an Institutional Review Board approved consent form before beginning the study (see Appendix C). Participant demographics were collected to compare groups (see Table 1). The group with autistic individuals contained participants with ages ranging from 20 to 28 (mean [M] = 22.80 standard deviation [SD] = 3.11). There were four males, one female, and an average of 5.6 years (SD=3.71) of driving experience with a range of 3 to 12 years. The neurotypical group contained participants with ages ranging from 22 to 30 (M = 24.32, SD = 2.11). There were eight males, 26 females, and an average 7.97 (SD=2.08) years of driving experience with a range of 5 to 14 years.

Table 1: Demographics by Group

Group	**Autism**	**Neurotypical**	**p-Value**
N	5	34	
Age M(SD) **Median (range)**	23.0 (3.17) 21.6 (20.3 – 28.3)	24.3 (2.07) 23.9 (21.6 – 30.1)	0.098
Males/Females	4/1	8/26	0.025*
Years Driving M(SD) **Median (range)**	5.6 (3.71) 5 (3 – 12)	7.97 (2.08) 7.25 (5 – 14)	0.024*

p<.05

Equipment

The “Tran-sit” is set up like a car with two adjustable seats with seatbelts. Both the driver and passenger side doors can open and there is a break and gas pedal on the driver side. The steering wheel is similar to a real wheel with a turn signal lever. The car model is set up with three screens to model the windshield. The participant was able to look at these screens to see the rear window and the two side mirrors in addition to the scene in front of them.

The driving simulator software is STISIM OT-DRIVE (Systems Technology Inc., 2013). This computer is password protected for confidentiality purposes. Studies have been done to find the validity of the STISIM (Lee, 2003; Mayhew et al., 2011). Lee (2003) compared older adults driving on both STISIM and an on-road assessment to validate the simulator. He found a positive association (0.716) between the simulated driving index and the road assessment index (Lee, 2003). Mayhew et al. (2011) investigated the validity of STISIM simulator driving. They found a significant correlation ($p<0.01$) between the on-road and simulator errors. This suggests a positive relationship between the two performances. Mayhew et al. (2011) also investigated if the simulated drive could discriminate between different driving skill levels. The results were all statistically significant - beginners compared to novices ($p = 0.04$), novices compared to experienced drivers ($p < 0.01$), and beginners compared to experienced drivers ($p < 0.001$) (Mayhew, et al., 2011).

An iPhone speaker was used in this study to play the music for the participants. It was placed at the front of the driving simulator to mimic where the sound comes from in a real car. Music sound levels were standardized so volume does not fluctuate between songs and participants using a RISEPRO Decibel meter. This will remove any unanticipated confounding variables.

Instrumentation

Modified Driving Habits Questionnaire

The *Modified Driving Habits Questionnaire* was used to gather personal information about an individual's driving in the past year to identify potential differences between the two participant groups. In their research study, Owsley, Stalvey, Wells, & Sloane (1999), found that this questionnaire has good test-retest reliability in older adults. The questionnaire has six domains: current driving status and miscellaneous issues, driving exposure, dependence on other drivers, driving difficulty, self-reported crashes and citations, and driving space (see Appendix D). Important questions to this study include driving speed compared to general traffic flow, the places they typically drive in a week and how far away they are, and the level of difficulty of specific driving conditions (raining, left-hand turns, interstates, high traffic, night). Other important questions are how many accidents they have been involved in and the spaces they have driven in (distant towns, outside North Carolina) (Owsley, Stalvey, Wells, & Sloane, 1999). While designed for older adults, the modified version is used frequently for studies on driving (Allison et al., 2018; Roe et al., 2017).

Adolescent/Adult Sensory Profile

The *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002) was used to gather information about an individuals' behavioral response to different everyday sensory experiences. This assessment has questions to cover the domains of visual, auditory, touch, taste/smell, movement, and activity level. Results are scored using quadrant scores – low registration, sensation seeking, sensory sensitivity, and sensation avoiding. The low registration quadrant measures passive behavioral responses associated with a high neurological threshold. These items identify behaviors such as missing stimuli or responding slowly. The sensation seeking quadrant measures active behavioral responses associated with a high neurological threshold. These items identify responses such as enjoyment and the pursuit of sensory stimuli. The sensory sensitivity quadrant measures passive behavioral responses associated with a low neurological threshold. These items identify responses such as noticing behaviors, distractibility, and discomfort with different sensory stimuli. Finally, the sensation avoiding quadrant measures active behavioral responses associated with a low neurological threshold. These items identify behaviors that are deliberate acts to reduce/prevent exposure to sensory stimuli (Brown & Dunn, 2002). The internal consistency method was used to find the consistency of responses to items in each sensory quadrant. The alpha values for various age groups and quadrant scores ranged from .639 to .775 (Pearson, 2019).

Performance Analysis of Driving Ability (P-Drive)

P-Drive (Patomella, 2014) was used as the dependent variable to measure driving performance. The *P-Drive* scores the driver's ability to drive safely and with competent maneuvers (Patomella & Bundy, 2015). There are four subcategories in the *P-Drive*: maneuvering (7 items relating to how a person handles the vehicle on the road such as steering and using their indicator), orienting (5 items relating to how a person positions themselves and follow directions such as positioning on the road, keeping distance, and following instructions), following regulations (3 items relating to following traffic signs such as yielding and obeying stop signs), and attending and responding (heeding) on different stimuli in the traffic context (10 items relating to paying attention to things in the person's environment such as fellow road users, to regulatory signs, and reacting) with a total score of 92 (see Appendix E). The specific items of changing gears and reversing (from subcategory maneuvering) will not be scored on the *P-Drive* as those driving components are not possible on a driving simulation. The 25 items are scored on a four-point criterion scale (1= incompetent performance, 2 = ineffective performance, 3= questionable and hesitant performance, and 4 = competent performance) (Patomella, 2014).

Patomella and Bundy (2015) performed a Rasch analysis which found that 96% of the therapists were within the acceptable range for goodness of fit meaning there was person response validity. The person separation reliability coefficient was 0.92 which means that the P-drive can separate drivers into more than four levels of driving ability. Additionally, it has been found that the Rasch scores and raw scores are highly correlated (0.88) (Patomella & Bundy, 2015) supporting the use of raw scores.

Patomella and Bundy (2015) determined the cutoff number for raw scores should be between 81-85 to determine if the driver is fit-to-drive. Drivers that fall in between this range should be considered in the "gray zone" and should be looked at more critically (Patomella & Bundy, 2015). A cutoff raw score of 81 was the most optimal when run through sensitivity and specificity analysis - it had a sensitivity of 0.93 and specificity of 0.92. The positive predictive value was 0.95 and the negative predictive value was 0.90 (Patomella & Bundy, 2015).

Procedure

The participants signed an informed consent form; after which they completed a demographic questionnaire, the Driving History Questionnaire, and the Sensory Profile before they drove on the simulator. Once the paperwork was completed, the researcher explained the instructions on how the simulator works and how the participant should use it. Once the participant understood how to use the simulator, the introduction and warm-up drive with the complete practice drive settings was initiated. The participant completed a practice drive to accommodate to the simulator. If the participant felt any simulator sickness, they reported it to the researcher who stopped the simulator immediately. This occurred with two neurotypical participants.

After the practice drive, the testing began following the established order from the counterbalancing table. The participants were given the instructions and time to ask any questions. After the participants completed the first drive, a second driving simulation was similarly completed with another environmental condition. After the second drive, the researcher offered a five-minute break. After the break, the participant completed the third and fourth drive with their corresponding environmental conditions will be completed. Throughout all four drives, the researcher scored the P-Drive.

After completion of all the simulations, the patient was debriefed about the study. While a participate completes a simulation, the simulator automatically records each scenario. Another trained rater watched the recordings and scored each drive using the P-Drive. The ratings from both observers were averaged together to be used for data analysis.

Data Analysis

There was one main type of outcome measure in this study: *P-Drive* raw scores. *P-Drive* raw scores were calculated by summing each *P-drive* item score (see Appendix E). Each subcategory of the *P-drive* (Maneuvers, Orientate, Follow Regulations, and Attending and Responding) also has a recorded raw score.

To describe the two groups' demographic data (age, gender, years driving), descriptive statistics were used. Mann-Whitney U tests were used to compare NT and ASD groups for differences in age, years of driving, and how many days of driving, while Fisher's exact tests were used to compare NT and ASD groups for differences in gender, speed compared to flow of traffic, quality of driving, accidents, driving outside NC, and sensory profile quadrant scores.

A 2x2x2 repeated measure ANOVA was used to analyze the *P-Drive* total score. No interaction effects and no music main effect were found, so the music factor was eliminated in remaining subcategory analyses. Because of the small sample size of the ASD group, limited variances were found when analyzing subcategories. Therefore, nonparametric tests, Mann-Whitney U test and Wilcoxon signed rank test, were used to analyze subcategory scores to determine significance.

Results

Adolescent/Adult Sensory Profile

The Adolescent/Adult Sensory Profile scores were collected to compare groups (see Table 2). The scores are reflective of a normal group as Crane et al. (2009) found that 94.4% of their ASD participants reported an extreme level of sensory processing on at least one sensory quadrant of the sensory profile (Crane et al., 2009). No significant differences were found between groups for sensory sensitivity. However, significant differences were found between groups for low registration, sensation seeking, and sensory avoiding.

Table 2: Summary of Sensory Profile Scores

Group		**Autism N (%)**	**Neurotypical N (%)**	**P-Value**
Low Registration	Similar to Most	2 (40%)	26 (76%)	0.033*
	More Than Most	1 (20%)	7 (21%)	
	Much More Than Most	2 (40%)	1 (3%)	
Sensation Seeking	Much Less Than Most	2 (40%)	1 (3%)	0.004**
	Less Than Most	3 (60%)	5 (15%)	
	Similar to Most	0	23 (68%)	
	More Than Most	0	3 (9%)	
	Much More Than Most	0	2 (6%)	
Sensory Sensitivity	Less Than Most	0	2 (6%)	0.489
	Similar to Most	3 (60%)	23 (68%)	
	More Than Most	1 (20%)	8 (24%)	
	Much More Than Most	1 (20%)	1 (3%)	
Sensory Avoiding	Less Than Most	0	2 (6%)	0.001**
	Similar to Most	1 (20%)	27 (77%)	
	More Than Most	1 (20%)	5 (15%)	
	Much More Than Most	3 (60%)	0	

*p<.05, **p<.001

Modified Driving Questionnaire

Table 3 shows the comparisons of the modified driving questionnaire which describes the two groups similarities and differences. There was no difference between quality of driving and how many days they drive. However, significant differences were found when comparing driving speed compared to the flow of traffic, number of accidents, and if they had driven outside of NC. Individuals with autism tended to drive about the same or slower than the flow of traffic while neurotypical individuals tended to drive faster than the flow of traffic. Neurotypical individuals also had fewer accidents compared to the individuals with autism. Finally, neurotypical individuals have driven outside of NC more than individuals with ASD.

Table 3: Comparisons of the Relevant Modified Driving Questionnaire Scores

Modified Driving Questionnaire Questions		**Autism**	**Neurotypical**	**P-Value**
Speed Compared to Flow of Traffic	**Somewhat Faster**	1	21	0.007**
	About the Same	2	13	
	Somewhat Slower	2	0	
Quality of Driving	**Excellent**	0	6	0.359
	Good	3	23	
	Average	2	5	
How Many Days They Drive M(SD) Median (range)		5.00 (1.58) 5 (3 – 7)	6.18 (1.46) 7 (2 – 7)	0.089
Accidents	0	2	33	0.004**
	1	2	1	
	2	1	1	
Driven Outside NC	**Yes**	1	24	0.047*
	No	4	10	

*p<.05, **p<.001

P-Drive **Scores**

Table 4 displays the means and standard deviations for total *P-Drive* scores separated by groups as well as the four individual subcategories. Table 5 shows repeated measures analyses for the total P-drive scores. Figure 2 shows a boxplot of the total scores.

Table 4. Means and Standard Deviations for Total *P-Drive* Scores and Each Subcategory by Group

P-Drive Measures			**Total**	**Maneuvers**	**Orientation**	**Following Regulation**	**Attending and Responding**
Autism	Hazard	Non music M(SD)	84.00 (7.91)	18.00 (1.37)	19.10 (1.34)	11.70 (0.67)	35.20 (5.45)
		Selected music M(SD)	82.90 (5.66)	17.30 (1.64)	19.00 (1.06)	12.00 (0.00)	34.60 (4.45)
	Wayfinding	Non music M(SD)	88.80 (3.33)	19.60 (0.65)	17.40 (2.72)	12.00 (0.00)	39.80 (0.27)
		Selected music M(SD)	88.20 (3.49)	19.50 (0.61)	18.00 (1.70)	10.80 (1.25)	39.90 (0.22)
Neurotypical	Hazard	Non music M(SD)	76.98 (8.20)	16.72 (2.42)	17.53 (2.02)	9.77 (2.07)	32.95 (3.97)
		Selected music M(SD)	76.89 (8.89)	16.82 (2.35)	17.80 (1.39)	9.69 (1.98)	32.53 (4.85)
	Wayfinding	Non music M(SD)	84.91 (6.01)	18.49 (1.66)	17.10 (2.03)	10.56 (1.11)	38.75 (2.51)
		Selected music M(SD)	84.77 (5.98)	17.73 (2.31)	17.36 (2.56)	10.38 (1.29)	39.30 (1.09)

Table 5. Repeated Measures ANOVA Analysis for Total *P-Drive* Scores.

Effects	**Total Score**	
	F	**P-value**
Drive	26.815	0.001**
Music	0.095	0.760
Group	4.172	0.049*
Drive*Group	1.287	0.264
Music*Group	0.021	0.885
Drive*Music	0.006	0.941
Drive*Music*Group	0.031	0.861
p<.05*; p<.001**		

Figure 2. Boxplot of Total Scores Displayed by Drive and Group

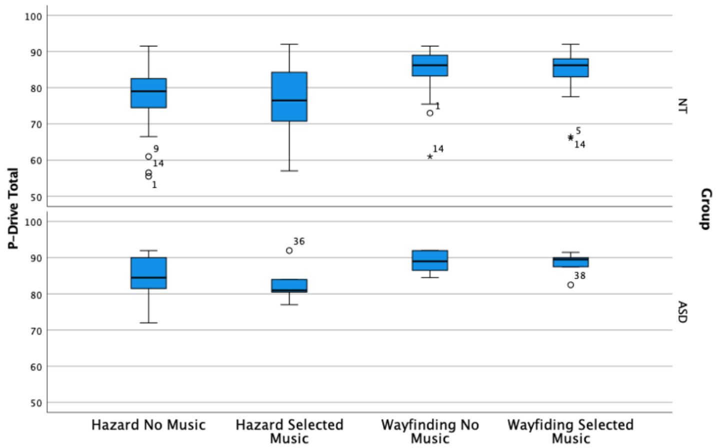


Table 6. Case Study Comparisons for the ASD Group

Participant		1	2	3	4	5
Gender		Male	Male	Male	Male	Female
Years Driving		12	3.5	3	5	5
Hazard Total Out of 92		83.50	92.00	84.25	81.25	76.25
Wayfinding Total Out of 92		89.75	89.50	87.00	87.35	89.00
Maneuver Out of 20	Hazard	17.50	20.00	17.25	17.25	16.25
	Wayfinding	19.75	19.75	19.75	19.25	19.00
Orientation Out of 20	Hazard	20.00	20.00	18.00	19.50	17.75
	Wayfinding	18.75	18.75	16.25	17.75	18.25
Following Out of 12	Hazard	12.00	12.00	12.00	12.00	11.25
	Wayfinding	11.25	11.25	11.25	10.50	12.00
Attending Out of 40	Hazard	34.00	40.00	37.00	32.50	31.00
	Wayfinding	40.00	40.00	39.75	39.75	39.75
Low Registration		Similar to most	Similar to most	More than most	Much more than most	Much more than most
Sensation Seeking		Much less than most	Less than most	Similar to most	Less than most	Much less than most
Sensory Sensitivity		Similar to most	Similar to most	Similar to most	Much more than most	More than most
Sensation Avoiding		More than most	Similar to most	Much more than most	Much more than most	Much more than most

Table 6 shows a comparison of data from each individual with ASD. Demographic information (gender and years driving) is displayed in addition to Sensory Profile scores and *P-Drive* subcategory scores for both drives. Visual and auditory processing subsections of the Sensory Profile were focused on as those senses are related to driving.

Case Study: Adolescent/Adult Sensory Profile

Participant 1:

- Overall Registration: Auditorily and visually similar to most in registering stimuli.
- Overall Seeking: Indicated much fewer seeking behaviors for visual and auditory stimuli.
- Overall Sensitivity: Auditorily and visually similar to most regarding sensitivity to stimuli.
- Overall Avoiding: Indicated more avoiding behaviors for auditory stimuli, however not bothered by visual stimuli.

Participant 2:

- Overall Registration: Auditorily and visually similar to most in registering stimuli.
- Overall Seeking: Indicated fewer seeking behaviors for auditory stimuli, however not bothered by visual stimuli.
- Overall Sensitivity: Auditory and visually similar to most regarding sensitivity to stimuli.
- Overall Avoiding: Auditory and visually similar to most regarding avoiding stimuli.

Participant 3:

- Overall Registration: Indicated lower registration for visual stimuli and auditory stimuli.
- Overall Seeking: Auditorily and visually similar to most regarding seeking out stimuli.
- Overall Sensitivity: Auditorily and visually similar to most regarding sensitivity to stimuli.
- Overall Avoiding: Indicated much more avoiding behaviors for visual and auditory stimuli.

Participant 4:

- Overall Registration: Indicated much lower registration for visual and auditory stimuli.
- Overall Seeking: Indicated fewer seeking behaviors regarding auditory stimuli, however not bothered by visual stimuli.
- Overall Sensitivity: Indicated much more sensitivity to visual and auditory stimuli.
- Overall Avoiding: Indicated much more avoiding behaviors for visual and auditory stimuli.

Participant 5:

- Overall Registration: Indicated much lower registration for auditory stimuli, however not bothered by visual stimuli.
- Overall Seeking: Indicated much fewer seeking behaviors regarding auditory stimuli, however not bothered by visual stimuli.
- Overall Sensitivity: Indicated more sensitivity to visual and auditory stimuli.
- Overall Avoiding: Indicated much more avoiding behaviors for visual and auditory stimuli.

Case Study: Driving Performance

Participant 1:

- Drove better on wayfinding drive than drive with hazards.
- Perfect score on orientation and following and lower scores on maneuvering and attending for hazard drive.

- Perfect score on attending, almost perfect scores on maneuvering and orientation, and lower scores on following for wayfinding drive.

Participant 2:

- Drove better on hazard drive than wayfinding
- Perfect score on hazard drive, including all subcategories
- Perfect score on attending, and near perfect score on maneuvering and orientation, lower scores on following

Participant 3:

- Drove better on wayfinding than hazard
- Perfect score on following and lower scores on maneuvering, orientation, and attending for hazard drive
- Almost perfect score on maneuvering, following, and attending, lower scores on orientation for wayfinding drive

Participant 4:

- Drove better on wayfinding than hazard
- Perfect score on following, almost perfect score on orientation, lower scores on maneuvering and attending for hazard drive
- Almost perfect score on maneuvering and attending, lower scores on orientation and following for wayfinding drive

Participant 5:

- Drove better on wayfinding than hazard
- Almost perfect score on following, lower scores on maneuvering, orientation, and attending for hazard drive
- Perfect score on following, almost perfect on maneuvering and attending, lower score on orientation for wayfinding drive

P-Drive Total Scores

Repeated measures ANOVA showed no overall differences between music conditions (F=0.095, p= 0.760) for the total *P-Drive* raw scores. However, there were significant differences between drives (F=26.815, p=0.001) and between groups (F=4.172, p=0.049). There were no significant interaction effects.

When comparing the two groups (ASD, NT), the ASD group scored higher on both types of drives (hazard, wayfinding) regardless of music condition (see Table 4 and Figure 2). When comparing the two types of scenarios, wayfinding scores were higher for both groups regardless of the music: ASD (M=88.80$\pm$3.33 for music, M=88.20$\pm$3.49 for no music) and neurotypical (M=84.91$\pm$6.01 for music, M=84.77$\pm$5.98 for no music).

After averaging out the music factor (see Table 7) performance on wayfinding was higher compared to the hazard drives for both groups; ASD group (M=88.50±1.29) and neurotypical group (M=84.85±4.68). In addition, the ASD group's performance was higher on hazard drives (M=83.45±5.71) compared to the neurotypical group (M=76.99±6.91).

Table 7. Means and Standard Deviations for *P-Drive* Total Scores Separated by Group with Music Factor Removed.

P-Drive Measures Highest Possible Score 92		Total
Autism	Hazard M(SD)	83.45 (5.71)
	Wayfinding M(SD)	88.50 (1.29)
Neurotypical	Hazard M(SD)	76.99 (6.91)
	Wayfinding M(SD)	84.85 (4.68)

***P-Drive* Subcategories**

To examine the subcategories, boxplots for each subcategory were created to look at data between groups (see Figure 3-6) without the music factor as it was not significant. Table 8 shows means, standard deviations, median, range and P-values for each subcategory .

Using Mann-Whitney U analysis, the Maneuvers category (highest score 20) showed no significant interaction between group and drive (p=0.307). Also, Mann-Whitney U tests showed no significant differences on the hazard drive between the two groups (p=0.423). Wilcox signed rank test found no significant differences between drives for the ASD group (p=0.068). However, the neurotypical group did significantly better (p=0.01) on the wayfinding drive (median=18.50) compared to hazard drive scenario (median=17.00). Finally, the ASD group (median=19.75) had significantly higher performance (p=0.004) on wayfinding compared to the neurotypical group (median=18.50).

Mann-Whitney U tests on the Orientate category (highest score 20) showed no significant interaction between group and drive (p=0.079). Wilcoxon signed rank tests found no significant differences between drives in the neurotypical group (p=0.089) or between drives in the ASD group (p=0.078). When looking at the wayfinding group specifically, no significant differences were found between drives (p=0.449). However, when looking specifically at the hazard group, the ASD group (median=19.50) scored significantly better (p=0.041) than the neurotypical group (median=17.88).

Mann-Whitney U tests on the Following Regulations category (highest score 12) showed no significant interaction between group and drive (p=0.117). When looking at the ASD group, no significant differences were found between the hazard and wayfinding drives (p=0.257). However, when looking at the neurotypical group, participants did significantly better (p=0.021) on the wayfinding drive (median=10.25, range=8.25-12.00) compared to the hazard drive (median=10.50, range=5.50-12.00). When looking at the hazard drive across both groups, the ASD group (median=12.00) performed significantly (p=0.001) better compared to the neurotypical group (median=10.50). When looking at the wayfinding drive across both groups, again the ASD group (median=11.25) performed significantly better (p=0.035) compared to the neurotypical group (median=10.25).

Mann-Whitney U tests on the Attending and Responding category (highest score 40) showed no significant interaction between group and drive (p=0.620). When comparing the two kinds of drives against the groups, no significant differences were found for hazard (p=0.328) or for wayfinding (p=0.062). When looking at the ASD group specifically, the differences between hazard and wayfinding were not significant (p=0.068). However, when looking at the neurotypical group specifically, their performance on the wayfinding drives (median=39.25) was significantly (p=0.001) higher than their performance on the hazard drives (median=32.63).

Figure 3. Boxplot Comparing Maneuvering Subcategory Between Drive and Groups

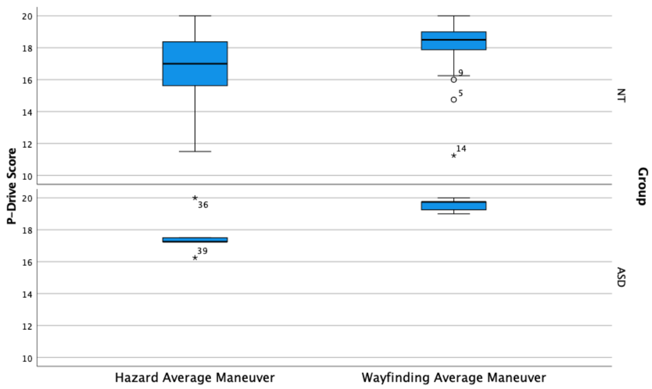


Figure 4. Boxplot Comparing Orientation Subcategory Between Drive and Groups

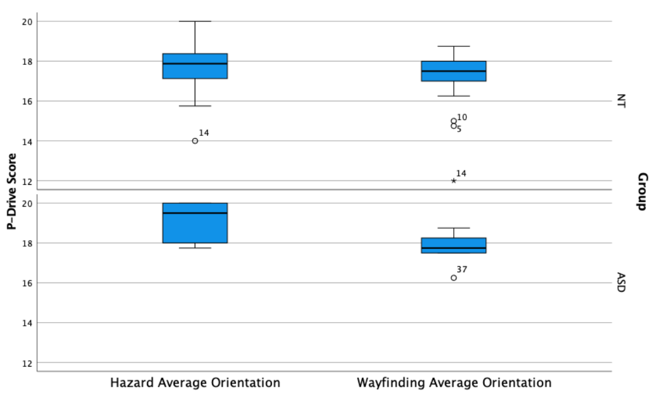


Figure 5. Boxplot Comparing Following Subcategory Between Drive and Groups

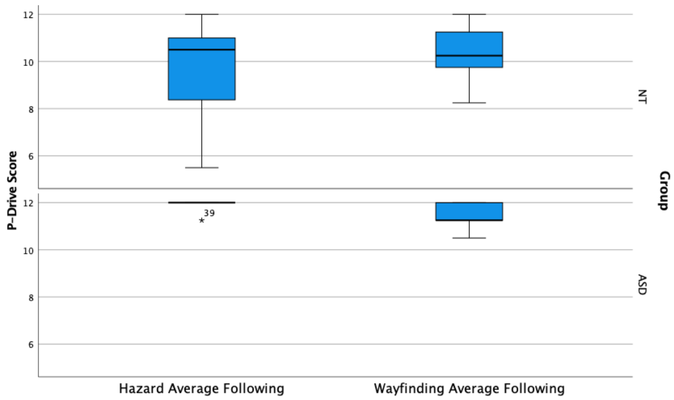


Figure 6. Boxplot Comparing Attending Subcategory Between Drive and Groups

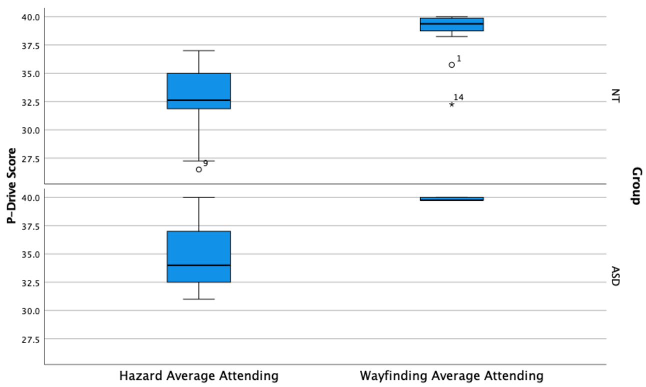


Table 8. Subcategory Descriptives and P-Values Without the Music Factor.

Subcategories Mean (SD) Median (Range)		Hazard	Wayfinding	P-value for Drive effect	P-value for interaction
Maneuvering Mean (SD) Median (Range)	NT	16.8 (1.98) 17.0 (11.50-20.00)	18.1 (1.70) 18.50 (11.25-20.00)	**0.001**†	0.307*
	ASD	17.7 (1.40) 17.25 (16.25-20.00)	19.6 (0.41) 19.75 (19.00-20.00)	0.068†	
	P-value for group effect	0.423*	**0.004***		
Orientation Mean (SD) Median (Range)	NT	17.64 (1.22) 17.88 (14.00-20.00)	17.27 (1.30) 17.50 (12.00-18.75)	0.089†	0.079*
	ASD	19.05 (0.34) 19.50 (17.75-20.00)	17.70 (0.94) 17.75 (16.25-18.75)	0.078†	

	P-value for group effect	**0.041**[*]	0.449[*]		
Following Mean (SD) Median (Range)	NT	9.77 (1.81) 10.50 (5.50-12.00)	10.45 (0.97) 10.25 (8.25-12.00)	**0.021**[†]	0.117[*]
	ASD	11.85 (0.34) 12.00 (11.25-12.00)	11.40 (0.63) 11.25 (10.50-12.00)	0.257[†]	
	P-value for group effect	**0.001**[*]	**0.035**[*]		
Attending Mean (SD) Median (Range)	NT	32.78 (2.97) 32.63 (26.50-37.00)	39.02 (1.48) 39.25 (32.25-40.00)	**0.001**[†]	0.620[*]
	ASD	34.90 (3.61) 34.00 (31.00-40.00)	39.85 (0.14) 39.75 (39.75 -40.00)	0.068[†]	
	P-value for group effect	0.328[*]	0.062[*]		

[*]: Mann-Whitney U test; [†]: Wilcoxon signed rank test

Volume Correlation

There was a significant negative correlation between the volume of the music and total *P-Drive* scores for the hazard drive (r=-0.354, p=0.032) (see Figure 7). For the wayfinding drive there was a nonsignificant positive correlation initially (r=0.239, p=0.148). However, after removing two outlier scores from the wayfinding drive (from the neurotypical group), there was a nonsignificant negative correlation (r=-.157, p=.361) (see Figure 8).

Figure 7. Correlations Between Hazard Average Volume and Hazard P-Drive Total Scores

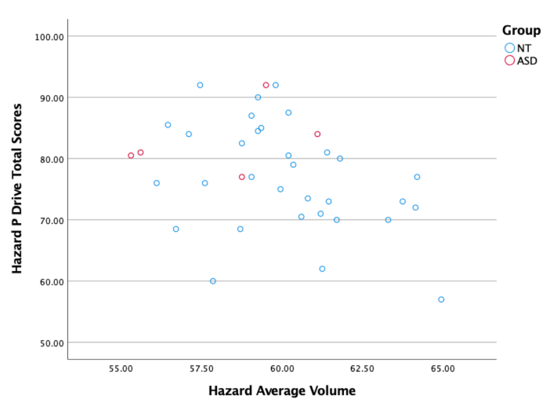
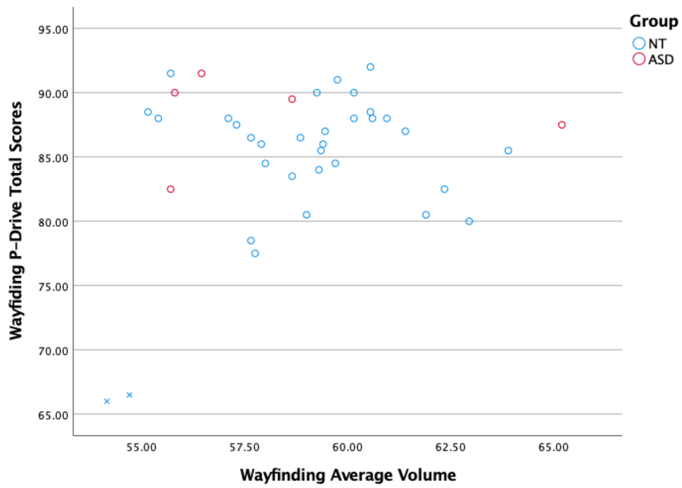


Figure 8. Correlations Between Wayfinding Average Volume and Wayfinding P-Drive Total Scores. Two Outliers are Flagged.



Discussion

The primary purpose of this study was to investigate if there were any significant differences in driving performance on an interactive driving simulator between experienced drivers with ASD and experienced drivers who are neurotypical. Surprisingly, although there were fewer experienced drivers with ASD, they performed significantly better than their experienced neurotypical counterparts in this study. These results suggest experienced drivers with ASD may be better drivers than their neurotypical peers. These results contradict previous research that indicated that drivers with autism performed worse on driving skills – specifically lane maintenance, signaling, and speed regulation - and overall performance (Classen, Monahan, & Wang, 2013; Classen, Monahan, & Hernandez, 2013). However, the participants with ASD in these studies were clearly inexperienced with driving performance since their average ages were 15.05 and 15.14 respectively compared to the mean of 23 years in this study. Yet, in a similar study with inexperienced drivers (mean age 17 years), Goehmann (2018) also found no overall differences between the ASD and neurotypical group. However, these results are consistent with Mayhew et al.'s (2011) study which found that simulated driving could discriminate between different driving skill levels, specifically between beginning, novice, and experienced drivers.

In addition to the higher total scores, drivers with ASD in this study also demonstrated the same or better driving performance on the individual categories of maneuvering, orientation, following regulations, and attending compared to their neurotypical peers. This offers support that given more appropriate training and driving experience, ASD drivers may actually become better drivers.

Surprisingly, there were no significant differences between driving with music and driving without music, indicating that music does not negatively or positively impact driving performance for drivers with and without ASD. This finding counteracts past research which stated that music decreases an individual's driving performance (Brodsky, 2001). Additionally, since music can help individuals with autism regulate some of their psychological behaviors (Burleson et al., 1989; Hillier et al., 2012), it was hypothesized that listening to music while driving may help create an optimal driving environment. This was one of the outcomes of a recent similar study (Goehmann, 2018) in which self-selected music improved driving performance for drivers with ASD, but not neurotypical. The difference may be that the previous study, done with younger and novice drivers, may react differently to music that experienced drivers.

Although music did not have a significant effect on driving performance, there was a significant correlation between higher volume music and negative driving performance on the drive with hazards for both groups. While not a significant correlation, there was also a slight negative correlation between higher music volume and negative driving performance on the wayfinding drive as well. This suggests that listening to louder music can cause poorer driving performance. These results go against past research (Goehmann, 2018) that found that volume of music does not affect driving performance. Music not having any positive or negative effects on driving performance was also interesting because four out of the five drivers with ASD reported that they avoided noisy settings. This suggests that their self-selected music was not overly stimulating to the drivers and therefore did not hinder their driving skills or their driving experienced compensated for any disruption by the music.

When comparing driving performance between the type of drives, with one having various hazards and the other focused on wayfinding, both groups drove better on the wayfinding drive. A possible explanation for these results may be that driving an unknown route caused them to pay more attention to the road and road rules. More likely however, is the fact that the simulator “hazard” scenarios are designed to have various hazards and will be more of a challenging scenario than wayfinding scenarios with less traffic. Nevertheless, it is interesting to consider each group.

The neurotypical drivers drove significantly better on maneuvering, following, and attending skills when driving the wayfinding drive compared to the drive with hazards. However, their orientation skills on their wayfinding drive were worse than on their hazard drive. This is likely because navigation/wayfinding skills are at the highest level of driving behaviors and the wayfinding drives demand more of this strategic processing skill than on the hazard scenarios which directed the driver.

Similarly, the drivers with ASD’s orientation skills were lower while wayfinding compared to the drive with hazards. However, one individual with ASD had low orientation scores on his wayfinding drive as he was unable to use the map to reach his destination. His low score affected the overall ASD group average on this subcategory, though as a group, the drivers with ASD had at least the same or better scores on all four subcategories with the wayfinding drives. This could be explained by individuals with high-functioning ASD having strengths in tasks that require perceptual organization and visualization, which using maps and following directions requires, (Ehlers et al., 1997) potentially giving them an edge over their peers.

Finally, higher scores on the maneuvering and attending subcategories could be explained by the fact that ASD drivers typically follow traffic rules more strictly and have more cautious driving styles (Ross et al., 2015). The driving history reported by the two groups in this study were significantly different in driving speed, with ASD drivers driving about the same or somewhat slower than the flow of traffic and neurotypical drivers driving somewhat faster.

Patomella and Bundy (2015) found that a cutoff raw score of 81 on the P-Drive was the most optimal and drivers who scored between an 81-85 should be looked at more critically (Patomella & Bundy, 2015). The average score for the hazard drive for the neurotypical group was lower than this cutoff score (76.99) along with the ASD average score (83.45). However, one of the reasons they might be lower on this drive is because the hazard drives are particularly challenging. This drive scenario has approximately eight different driving hazards to avoid which might be more than an average drive would have. Scores for both groups on the wayfinding drive were higher, which could be explained by there being no hazards for them to avoid.

Studies have found that driving simulator performance is highly correlated with on-road driving performance (Lee, 2003; Mayhew et al., 2011; Shechtman et al., 2009) which supports translating the results of this study to on-road driving. The experienced ASD group performed better than their neurotypical peers no matter what music condition they were in on the driving simulator. It is therefore assumed that they would perform the same on-road as well. This assumption is also supported by the fact that these drivers had experience. They had spent years learning and gaining driving experience on the road, so it would be expected that they make similar correct and incorrect responses on the simulator that they do on the road.

Case Study

Participant 1

Participant one's lack of engagement in visual and auditory stimuli might be clinically evident in him choosing not to listen to the radio when driving or not driving with the sun shining in his eyes. His avoidance of auditory stimuli might be evident in poorer driving performance when listening to music. However, his driving scores reflect that he was able to handle listening to music while driving. This may suggest that listening to music he picks out himself may be more tolerable and less bothersome than random music. His registration level for auditory and visual stimuli was similar to most people, which may explain why he was able to see and respond to road signs and the hazards in his environment. His many years of driving experience could also help explain why he performed so well on each drive even though he avoids auditory stimuli.

Participant 2

Participant two's lack of engagement in auditory stimuli may present itself as not listening to the radio when driving and not talking to himself through driving directions. However, his driving scores reflect that he was able to handle listening to music. In fact, his scores on his hazard drives were perfect, indicating that music did not distract him from avoiding the many hazards he had to drive through. In addition, he scored very high on his wayfinding drive, suggesting that music did not negatively his ability to successfully use a map. The fact that he registered, did not avoid, and was not sensitive to auditory and visual stimuli may also explain why his performance was high on both types of drives.

Participant 3

Participant three's lower registration for visual and auditory stimuli could present in him missing street signs and hazards moving suddenly in front of him and him missing the median line causing him to drive in the wrong lane. He could also miss verbal GPS directions and sirens. His avoidance of visual and auditory stimuli could be seen if he avoids listening to music in the car, him being distracted by people talking to him as he drives, and avoiding driving at night so he doesn't have to deal with glares. His scores reflect that he did miss regulatory signs as he would frequently drive over the speed limit. He also struggled to use the map to wayfinding suggesting he missed street signs and building cues. He also had the least amount of driving experience out of the group, which could be related to his lower scores. However, his scores indicate that music was not a distraction for him, suggesting that music he self-selected may be less bothersome.

Participant 4

Participant four's lower registration for visual and auditory stimuli could present as him missing street signs and hazards that move out in front of him suddenly. He also might not hear car horns and brake sounds indicating someone is moving or stopping around him. Him not seeking out, avoiding, and being sensitive to auditory stimuli may present as him not listening to the radio or talking to other people while he is driving. Him being sensitive to and avoiding visual stimuli may present as driving with sunglasses or not driving during the brightest times of the day. His scores reflect that he did miss seeing street signs as he frequently drove the incorrect speed and took a few wrong turns when completing the wayfinding drives. His scores also reflect that he did not notice and respond to pedestrians and cars that moved out in front of him as he crashed frequently in his hazard drives.

Participant 5

Participant five's lower registration, sensitivity, willingness to seek out, and avoidance to auditory stimuli may present itself as her missing car horns and brake sounds when they move around her. It may also present as her not turning on the radio or talking to people while she is driving. Her sensitivity and avoidance to visual stimuli may present as not wanting to drive at night to avoid having to deal with driving and break light glares. Her scores reflect that she crashed multiple times during her hazard drive, suggesting that she missed the auditory cue that they were around her. However, her ability to register visual stimuli may explain why she was able to complete the wayfinding drives so successfully as she was able to see the street signs she needed to turn on.

Conclusion

Individuals with high functioning autism are a diverse group when it comes to how they respond to sensory information. The variability in these individuals' responses align with the typical ASD population (Crane et al., 2009) and would be similar to the individuals a therapist would see in their clinic. Even though each individual struggled with different sensory stimuli and made some driving errors, they still were able to drive overall better than their neurotypical peers suggesting that their sensory differences can be managed and allow them to function successfully when driving. Many of the individuals in this group were bothered by auditory stimuli; however, their scores were not significantly worse when listening to their own self-selected music. This suggests that their self-selected music might have turned into calming background noise that was not distracting. This aligns with past research that suggests that background music can increase task accuracy, decrease off-task responses, and decrease anxiety (Darrow & Armstrong, 1999; Hillier et al., 2012) in individuals with ASD all of which will help them drive better.

Implications for Occupational Therapy Practice

This study informs occupational therapists that listening to music does not negatively or positively affect individuals with ASD when they drive, going against past research (Brodsky, 2001). Music can have positive effects on ASD drivers when they are beginners (Goehmann, 2018) by helping these individuals calm down and feel less anxious (Burleson et al., 1989; Hillier et al., 2012). However, once they gain driving experience, they no longer need music to drive successfully. If they need music to help them organize their thoughts, music can be used, but it is not required. Therapists can use their clinical judgment and expertise when working with individual with autism to determine if incorporating music into their sessions would be beneficial.

This study also informs occupational therapists that individuals with ASD might make more driving errors when they are novices, but as they gain more experience, they are able to drive safely and successfully. As their experience increases and they gain proficiency in tactical and operational driving skills, drivers with ASD can drive, just as well, if not better, than neurotypical drivers as they are more likely to follow speed limits and other driving rules. Experienced drivers with ASD are able to control their speed, wayfind, position themselves, and attend to their environment competently and better than their neurotypical peers.

This study also shows the importance of teaching navigational skills when working with individuals with autism. When taught these skills, ASD drivers can be very successful in navigating maps and written directions. Wayfinding, following instructions, and planning are all skills that are related to wayfinding that individuals with ASD can excel at. Navigation requires perceptual organization and visualization, which are areas individuals with ASD can excel at (Ehlers et al., 1997). Therapists should incorporate these skills into their sessions to help individuals with ASD increase their driving ability.

Occupational therapist can also incorporate driving simulators into their intervention plans. Many individuals with ASD are interested in getting their driver's license and it is a goal therapist can help them achieve (Curry et al., 2018). Novice drivers with ASD can frequently make more driving errors (Classen, Monahan, & Hernandez, 2013; Classen, Monahan, & Wang, 2013) so using a driving simulator during early driving interventions may be a safer alternative to driving on the road. Once the driver has become proficient on the simulator, they will have gained more driving experience and will be less likely to make driving errors. The therapist can then transition them to driving on the road, knowing that their skills learned on the simulator will transition to on-road (Lee, 2003; Mayhew et al., 2011; Shechtman et al., 2009).

Limitations

One limitation of this study was the small sample size in the autism group. COVID-19 severely limited the number of participants recruited. Because of this, traditional parametric statistical testing could not be performed on that group's data. This limits the impact the results have. To minimize the effects of this limitation, non-parametric tests were used on the data to find significant results.

Another limitation of this study was that the specific items of changing gears and reversing (from the maneuvering subcategory) were not scored on the *P-Drive* as those driving components were not possible on a driving simulator. This limitation could affect the measure, however other studies have removed these items without problems (Baran, 2020; Goehmann, 2018).

A third limitation of this study was the use of the driving simulator. In a perfect study, it would be best to observe participants on the road in real-life driving scenarios to get the most accurate picture of each participant's driving skills. However, it was not possible or safe to go on-road with each participant for this study. Previous research has found a similarities between driving on a simulator and driving on the road to minimize the effects of this limitation (Lee, 2003; Mayhew et al., 2011; Shechtman et al., 2009).

Future Research

Since there were clear differences in both the drives and groups, research is clearly needed to explore this question with a larger sample. In addition, potential research questions should include examining how music affects individuals with autism when they drive with true on-road driving in diverse environments (urban, rural). While driving simulator performance is similar to driving performance on-road, it would be best to observe participants on the road driving in with real traffic and hazards to get the best picture of each participant's driving skills. Driving on-road would also remove the possibility of simulator sickness, which affected two neurotypical participants in this study.

In addition, future research should include more interview questions to get a more comprehensive understanding of each individual's driving history. Questions should be about reasons why they crashed, what environments they prefer and don't prefer to drive in, and why they haven't driven outside of North Carolina. This information would be used to supplement the modified driving questionnaire and sensory profile data to get a better picture of the full background of each participant and potentially find patterns within the various sensory profiles to use as guidance for driving options and preferences.

Conclusions

Driving is a complex skill that requires many performance skills, visual skills, and cognitive skills to work together. Past literature indicated that individuals with ASD would experience difficulties in sensory processing and have difficulties with driving compared to their neurotypical peers. However, these findings found that experienced individuals with ASD drove better than their neurotypical peers, suggesting there is potential for ASD individuals to be successful drivers once they get more experience.

Past studies have looked at how music impacts different occupations, including driving, with mixed results. This study supports the idea that self-selected music does not affect driving performance of experienced drivers, both with and without ASD, when using an interactive driving stimulator. This means that drivers can choose to listen to music without negatively impacting their driving performance. Music has been found to help individuals with autism with task accuracy, relaxation, and increasing self-esteem. Therefore, for drivers with ASD, listening to self-selected music may help them modulate their environment and behaviors, allowing them to successfully perform the complex skill of driving.

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Appendix A:

IRB Approval Letter

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

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: Sydney Romer
CC: Anne Dickerson
Date: 5/20/2020
Re: UMCIRB 20-001125
Effects of Background Music on Experienced Driving Performance

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 5/19/2020. The research study is eligible for review under expedited category # 6,7. The Chairperson (or designee) deemed this study no more than minimal risk.

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

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

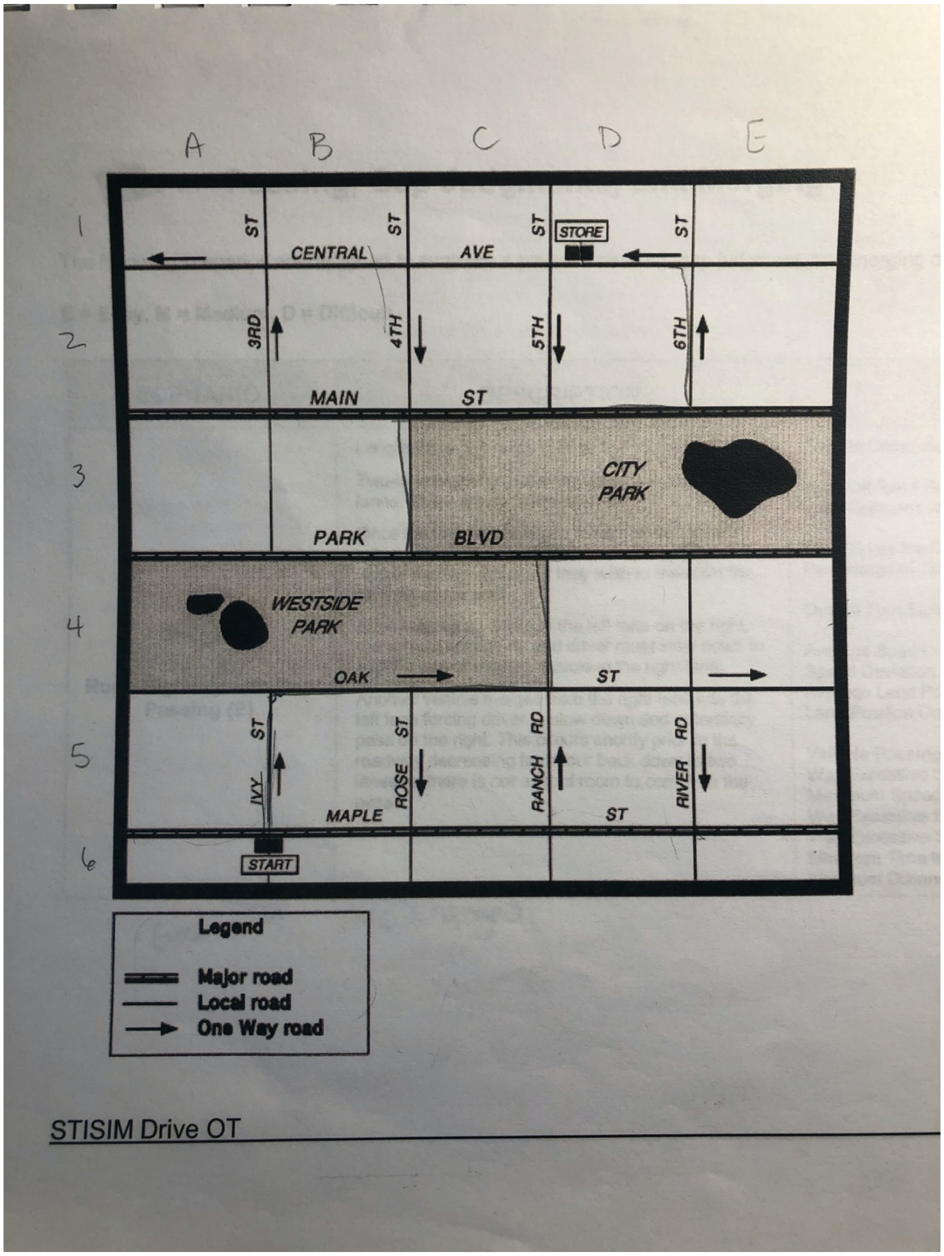
The approval includes the following items:

Name	Description
Demographic Questionnaire	Surveys and Questionnaires
Email Flyer	Recruitment Documents/Scripts
Flyer	Recruitment Documents/Scripts
Informed Consent	Consent Forms
Modified Driving Habits Questionnaire.docx	Surveys and Questionnaires
P-Drive and Manual	Standardized/Non-Standardized Instruments/Measures
Romer Thesis Proposal	Study Protocol or Grant Application

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

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

Appendix B:
City Map



Appendix C:
IRB Consent Form

Study ID:UMCIRB 20-001125 Date Approved: 7/28/2020 Does Not Expire.

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Effects of Background Music on Experienced Driving Performance in Individuals with Autism Spectrum Disorder Compared to Neurotypical Individuals

Sponsor/Funding Source: College of Allied Health Sciences Thesis/Dissertation Research Grant

Principal Investigator: Sydney Romer (Person in Charge of this Study)
Institution, Department or Division: Occupational Therapy Department
Address: East Carolina University Health Sciences Building, 3305 Greenville, NC 27834
Telephone #: 770-696-7700

Participant Full Name: ___________________________________Date of Birth: ___________________
Please PRINT clearly

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?
The purpose of this research is to see what affect background music can have on you while you drive. You are being invited to take part in this research because you have at least three years driving experience and are under the age of 30. The decision to take part in this research is yours to make. By doing this research, we hope to learn if there are differences in driving performance when listening to music versus when you are not listening to music. We also hope to learn if there are difference in music effects between the two different driving scenarios.

If you volunteer to take part in this research, you will be one of about 64 people to do so.

Are there reasons I should not take part in this research?
I understand I should not volunteer for this study if I do not have at least three years of driving experience or if I know I get motion sick.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research will be conducted at the East Carolina Allied Health Campus. You will need to come to *Health Science Campus, Room 1330* one time during the study. The total amount of time you will be asked to volunteer for this study is 1 hour.

What will I be asked to do?
You will be asked to do the following:

Title of Study:

First you will fill out a driving questionnaire survey and an Adult Sensory Profile to see what experiences you have had while driving and to see how you process sensory information. Then you will spend around 45 minutes using a driving simulator while listening to music you selected. You will complete four different simulated drives (two wayfinding and two hazard). There will be breaks during the study in between drives.
As you are completing the drives on the simulator, the principle investigator will be using an observational tool to score your driving performance.

The simulated is designed to record as it runs; however, you will not be in them. The videos will only be viewed by two people to determine reliability. The videos will be coded and kept secure on the simulator computer software. The data will be kept indefinitely.

What might I experience if I take part in the research?
The only risk you may experience in this study is motion sickness. There are no other any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. We don't know if you will benefit from taking part in this study. There may not be any personal benefit to you but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
We will be able to pay you for the time you volunteer while being in this study in the form of a $40 gift card.

Will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

How will you keep the information you collect about me secure? How long will you keep it?
Data will be kept in a secure location in a locked room and will be kept on pirate drive. Identifiers will be removed and the data will be coded. Video recordings will not be used for anything other than the purpose of this research. When the study is complete, identifies will not be on any materials. The only identifiers will be on this consent form. Data will be kept indefinitely.

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at *770-696-7700* (days, between *8-5 Monday through Friday)*

If you have questions about your rights as someone taking part in research, you may call the University & Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914

Title of Study:

Is there anything else I should know?

Identifiers might be removed from the identifiable private information or identifiable biospecimens and, after such removal, the information or biospecimens could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from you or your Legally Authorized Representative (LAR). However, there still may be a chance that someone could figure out the information is about you.

I have decided I want to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

Appendix D:
Modified Driving Questionnaire

Current Driving

1. Do you wear glasses or contacts when you drive? ____ Yes ____ No

2. Do you wear a seatbelt when you drive? ____ Always ____ Sometime ____ Never

3. Which way do you prefer to get around?
   ____Drive yourself
   ____Have someone drive you
   ____Use public transportation or a taxi

4. How fast do you usually drive compared to the general flow of traffic?
   ____Much faster ____Somewhat slower
   ____Somewhat faster ____Much slower
   ____About the same

5. Has anyone suggested over the past year that you limit your driving or stop driving?
   ____ Yes ____ No

6. How would you rate the quality of your driving?
   ____ Excellent ____ Good ____ Average ____ Fair ____ Poor

7. If you had to go somewhere and didn't want to drive yourself, what would you do?
   ____ Ask a friend or relative to drive you
   ____ Call a taxi or take the bus
   ____ Drive yourself regardless of how you feel
   ____ Cancel or postpone your plans and stay at home
   ____ Other (specify):___________________________

Exposure

8. In an average week, how many days per week do you normally drive? ____ days per week

9-11. Please pause for a minute and consider all the places you drive in a typical week. Check those places and tell me how many times per week and the number of miles.

____	Store	____	How many times a week?	____	Miles from home
____	Church	____	How many times a week?	____	Miles from home
____	Work/School	____	How many times a week?	____	Miles from home
____	Relative's Home	____	How many times a week?	____	Miles from home
____	Friend's Home	____	How many times a week?	____	Miles from home
____	Out to eat	____	How many times a week?	____	Miles from home
____	Appointments	____	How many times a week?	____	Miles from home

Are there other places you go in a typical week?

______________	____	How many times a week?	____	Miles from home
______________	____	How many times a week?	____	Miles from home
______________	____	How many times a week?	____	Miles from home

Avoidance

13a. During the past 3 months, have you driven while it has been raining?

____ Yes (go to 13b)
____ No (go to 14)

13b. Would you say that you drive when it is raining with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

14a. During the past 3 months, have you driven alone?

____ Yes (go to 14b)
____ No (go to 15)

14b. Would you say that you drive alone with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

15a. During the past 3 months, have you parallel parked?

____ Yes (go to 15b)
____ No (go to 15c)

15b. Would you say that you parallel park with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

15c. Why do you not parallel park

____ Not necessary – not many parallel parking spots
____ Visual Problems
____ Never learned how
____ Other (specify): ____________________

16a. During the past 3 months, have you made left-hand turns across oncoming traffic?

____ Yes (go to 16b)
____ No (go to 17)

16b. Would you say that you make left-handed turns in traffic with: (Check one answer)

____ No difficulty at all
____ A little difficulty

____ Moderate difficulty
____ Extreme difficulty

17a. During the past 3 months, have you driven on interstates or expressways?

____ Yes (go to 17b)
____ No (go to 18)

17b. Would you say that you drive on interstates or expressways with: (Check one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

18a. During the past 3 months, have you driven on high-traffic roads?

____ Yes (go to 18b)
____ No (go to 19)

18b. Would you say that you drive on high-traffic roads with: (Check one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

19a. During the past 3 months, have you driven in rush hour traffic?

____ Yes (go to 19b)
____ No (go to 20)

19b. Would you say that you drive in rush hour traffic with: (Check one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

20a. During the past 3 months, have you driven at night?

____ Yes (go to 20b)
____ No (go to 21)

20b. Would you say that you drive at night with: (Check one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

Crashes and Citations

21. How many accidents have you been involved in over the past year when you were the driver? Please tell me the number of all accidents, whether or not you were at fault.

____ accidents

22. How many accidents have you been involved in over the past year when you were the driver where the police were called to the scene?

____ accidents

23. How many times over the past year have you been pulled over by the police, regardless of whether you received a ticket?

____ times

24. How many times in the past year have you received a traffic ticket (other than a parking ticket) where you were found to be guilty, regardless of whether or not you think you were at fault? ____ times

Driving Space

25. During the past year, have you driven in your immediate neighborhood?

____ Yes ____ No

26. During the past year, have you driven to places beyond your neighborhood?

____ Yes ____ No

27. During the past year, have you driven to neighboring towns?

____ Yes ____ No

28. During the past year, have you driven to more distant towns?

____ Yes ____ No

29. During the past year, have you driven to places outside the state of NC?

____ Yes ____ No

30. During the past year, have you driven to places outside of NC, SC, or VA?

____ Yes ____ No

Modified from the Driving Habit Questionnaire (DHQ)

Owsley, C., Stalvey, B., Wells, J., Sloane, M.E. (1999) Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology: Medical Sciences* 54A: M203-M211.

Appendix E:
P-Drive Scoring Sheet

P -Drive

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Performance Analysis of Driving Ability

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

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

Actions (1-26):

Maneuvers

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

Orientate

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

Follow regulations

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

Attending and responding (heeding)

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

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

Other information:

Standard route ☐ Special route ☐

Signed consent form ☐

Time on-road (min):________

OUTCOME: ☐ Pass ☐ Fail

☐ Fail with lessons

☐ Other____________

Appendix F:
P-Drive Scoring Manual

P -Drive

P-Drive Items to Score (N = 25):

1. Steering

This item is about steering the vehicle in a competent and safe manner. The grading is influenced by the quality of the grasp of the steering wheel and coordination of steering to maintain the correct road position.

Examples of scoring:

4 = Has no problem steering the vehicle in a competent and safe manner.
3 = Steers the vehicle with some hesitancy. Example: Uses a questionable grip of the steering wheel such as one handed steering.
2 = Unsafe steering has a potential to create a risky situation. Example; Steering in a risky manner such as hitting the curb.
1 = Loses control of the steering or incompetent steering that has potential for crash or running off the road. Intervention is required to assist with steering.

2. Changing gears

This item concerns changing gears in a competent and secure manner using hand movements. The client's ability to select the correct gear in relation to the speed of the vehicle and the traffic situation is observed. Smooth operation of the gear lever and ability to change gear without looking at the gear box (manual car) is evaluated. If the client is driving an automatic car make sure that 'Automatic' is ticked in the scoring sheet. **It is common to score 4 when client is using automatic gear**.

Examples of scoring:

4 = Changes gears in a competent and secure manner.
3 = Changes gears with some hesitancy, Example: Does not find the correct gear immediately or smoothly (fumbles with the gearshift).
2 = Chooses the wrong gear repeatedly or not timing the shifting correctly affecting the rhythm and safety of driving.
1 = Does not change gears or has significant difficulties shifting gears in a smooth or competent manner. Example: Must look at the manual gear stick to change gear.

3. Using pedals

This item is about using the pedals in a competent and secure manner during the driving test. Observe the client's ability to locate the pedals accurately and apply the brake and accelerator in a smooth and coordinated manner without looking at pedals.

Examples of scoring:

4 = Competent and secure use of pedals
3 = Shows hesitancy in the calibration of pressure on one or both pedals. Example: Slow or late in taking action, but does not impinge action.
2 = Delay in the use of pedals leads to a potentially risky situation. For example: Uses too little pressure on the brake, stops abruptly causing difficulty for vehicles behind.
1 = Makes mistakes or physically does not use the pedals in a secure manner. Examples: Brakes too late, mistakes the brake for accelerator or reverse, applies the accelerator and brake at the same time, physically cannot use the pedals.

4. Controlling speed - too slow

This item is about being able to control and adapt the vehicle's speed without being too slow for the conditions. Observe ability to drive at a speed appropriate to the conditions and without slowing other traffic down. A low speed that is unjustified and hinders other traffic will lead to a lower score.

Examples of scoring:

4 = Selects and adapts an appropriate speed for the traffic conditions without hindering other road users.
3 = Choice of speed is questionable. Example: Drives at a speed that would have some other road users overtake or pass the client's vehicle.
2 = Choice of speed is unjustified and too slow for the situation in that all drivers are needing to overtake or pass the client's vehicle or other road users are significantly slowed down. Example: Drives approximately at 25-30 mph on a 40-50 mph road where it is warranted to keep up the speed.
1 = Does not maintain a speed appropriate for other traffic and the road conditions so that driving is not performed in a safe and competent manner. Example: Causes other road users to slow or brake suddenly, potentially increasing the risk of a crash.

5. Controlling speed- too fast

This item is about being able to control and adapt speed according to the traffic situation without driving too fast. Ability to stay within the speed limit and reduce speed when necessary for the situation (e.g., due to other traffic, school zones or pedestrians) is observed. Driving at a speed that is above the client's ability or inappropriate for the traffic conditions will lower the score.

Examples of scoring:

4 = Selects and adapts an appropriate speed for the traffic situation by remaining within the speed limit.
3 = Choice of speed is questionable. Example: Overtakes a slower vehicle going slightly over speed limits.
2= Choice of speed is risky for driving conditions or drives at a speed potentially above driver's ability to safely control the vehicle.
1= Does not adapt speed for driving conditions, driving too fast and it unsafe manner. Repeatedly drives over the speed limit or for the road conditions (rain, traffic, intersections).

6. Using turn signals (indicators)

This item concerns the use of indicators in a safe and appropriate manner. Difficulties that would lead to a lower score include; 1) Difficulties in planning and correctly sequence the use of the indicator, or 2) incorrect use of the left and right indicator depending of the direction of the turn or 3) applying the indicator unnecessarily (when not turning). Although many drivers have bad habits, this should be scored for the safety and competence of the skills observed.

Examples of scoring:

4 = Uses the correct indicators in an appropriate manner.
3 = Misses or is late in application of the indicator without compromising safety.
2 = Does not use the indicator consistently, but use does not lead to any risky issues in the traffic situation**.**
1 = Does not use the indicator when needed to prevent a risky situation or uses the indicator I inaccurate way causing a risky situation, such as indicating the wrong direction without correction

7. Reversing

This item is about being able to drive the car in reverse gear in a competent and safe manner. The client's ability to reverse the car appropriately is defined by 1) correct road position and 2) correct vision control (mirror and over the shoulder checks; back-up camera/visual display if used routinely).

Examples of scoring:

4 = Drives the vehicle in reverse in an appropriate manner.
3 = Drives hesitately when reversing**,** or asks for minor help.
2 = Requests or needs assistance (verbal prompting) to be able to reverse, takes significant amount of time to complete, does not positions the vehicle adequately, or demonstrates lack of attention to the environment behind the vehicle when reversing.
1 = Does not reverse in a safe, appropriate, and competent manner without assistance.

8. Following instructions

This item is about being able to follow verbal instructions in a competent and secure manner. Ability to follow verbal instructions without hesitation or the need for prompts or repeated instructions or the need for clarification is observed.

Examples of scoring:

4 = Follows instructions appropriately and in accordance with situational needs.

3 = Hesitates with directions or asks a single confirming question such as "*Which way did you say to turn?*"

2 = Does not follow instructions, needs repeated directions, or needs cues to follow the instructions.

1 = Does not follow instructions and requires significant intervention to manage traffic situations.

9. Wayfinding

This item is about being able to find the way to a specified location in a competent and safe manner. The client's ability to follow clues from the environment and ability to find the way is observed. If the client chooses an incorrect route although sufficient signage was present, a lowered score is given.

Examples of scoring:

4 = Easily finds the way to a specific location using an appropriate, safe, and competent manner.

3 = Hesitates in wayfinding and may ask a question to clarify route (e.g. "Was it here that I should have turned?"). May make an incorrect turn route but realizes the mistakes and corrects it independently by taking another route or retracing the original route.

2 = Requires repeated instructions to be able to find the way or makes repeated mistakes in wayfinding.

1 = Does not arrive at specific location or route even with repeated and clear instructions.

10. Positioning on the road

This item is about being able to select the correct position on the road in a competent and safe manner. Ability to stay within the lane, maintain a straight course, avoid cutting corners or taking wide corners, and maintain appropriate buffer zones from other vehicles and object in other lanes or at the side of the road is scored.

Examples of scoring:

4 = Maintains a correct and secure lane position on the roadway.

3 = May move into an incorrect position on the road but corrects the mistake. Becomes aware of any incorrect lane position and self corrects without prompting. Hesitates in the choice of lane when required.

2 = Lane position is too much to the right or the left, does not maintain correct lane position or chooses incorrect lane. Does not present a risk for a crash.

1 = Does not maintain correct lane position on the road even with cueing. Repeatedly drives too close to other vehicles or objects on either side of the lane. Chooses incorrect lane which may cause a crash, as in a two lane turn and moving into the other lane).

11. Keeping distance

This item is about maintaining adequate buffer zones (distances) around the vehicle and selecting the right distance to other cars and objects. This includes being able to keep a secure distance to pedestrian crossings, traffic lights, stop lines, other vehicles, moving and still objects, parking spaces, and/or road signs.

Examples of scoring:

4 = Keeps an adequate buffer zones or distances to objects in front and to the side of the vehicle.
3 = Buffer zones to other objects are too close or too far but does not impact safety. Does not adapt to distances smoothly as in stopping abruptly just before the stop line.
2 = Buffer zones are too close which may create a risky situation, as in tailgating, although corrects when cued.
1 = Does not keep a safe distance without intervention or stops the vehicle over the stop line in an intersection when traffic lights are red putting the vehicle at risk for a crash.

12. Planning

This item is about being able to plan driving maneuvers and sequences in a competent and safe manner. This includes being able to plan the next maneuver, such as changing lanes before an intersection, slowing down before a roundabout and knowing when to merge into a lane on a highway. (The item is about finding a flow in the driving and being able to plan the driving from place A to place B).

Examples of scoring:

4 = Competently plans driving maneuvers in a way that facilitates performance of other actions
3 = Hesitates in the planning of the driving maneuvers. Does not follow directions to a specified place or positions, but chooses a different route with the same outcome (although signage was present).
2 = Does not plan appropriate maneuvers resulting in a different outcome from expected. Poor planning may put vehicle in risky situations.
1 = Does not plan appropriate or safe maneuvers resulting in intervention or several risky actions.

13. Yielding

This item is about being able to yield to other traffic in compliance with road law in a competent and safe manner. This includes understanding when specific road rules apply and being able to drive in a way that indicates the rules are understood.

Understanding includes both for when yielding is needed as well as when other traffic needs to yield for him or her.

Examples of scoring:

4 = Yields appropriately for traffic situation in a competent and safe manner and in compliance with road laws.
3 = Hesitates in yielding such as in merging
2 = Does not yield according to the road rules or needs to be cued to yield appropriately and safely. Example: Does not slow down enough so that other vehicles can pass or yield while in a roundabout.
1 = Repeatedly fails to yield according to road rules leading to risky driving needing intervention.

14. Obeying stop signs and traffic lights

This item is about being able to stop the vehicle at a stop sign or traffic light in a competent and safe manner including being able to decide when to stop in accordance with current road law. Ability to drive in a confident and competent manner without hesitating is observed (demonstrating knowledge of the road rules for stopping). Failure to stop the car completely at a stop sign leads to a lower score.

Examples of scoring:

4 = Obeys the stop regulations and road laws appropriately and adequately.
3 = Hesitates to stop at stop sign or traffic light.
2 = Inadequate actions at stop signs or traffic lights including not stopping completely as in yielding instead of stopping.
1= Does not stop at stop sign or red light or slowing down to assess risk, requiring intervention.

15. Following speed regulations

This item is about being able to follow speed regulations in a competent and safe manner, without speeding. Violating the speed limit is a more severe error in low speed zones such as 25 mph school zones. Be aware that only speeding is scored for this item. If the driver is driving is too slow or hindering other traffic but the speed limit is not exceeded, this is still scored as a 4.

Examples of scoring:

4 = Adheres to posted speed limits.
3 = Hesitates in response to speed limit signs and/or drives up to 5 mph over the limit
2 = Drives over the speed limit; but within 10 mph over the limit.
1 = Drives consistently over the speed limit and over the 10 mph limit; Potential risky situations due to speeding.

16. Attending and responding to the road environment ahead

This item is about being able to attend to the forward road environment ahead in a competent and safe manner, including attending to and acting upon stimuli in the traffic environment (eg. other cars, signs and pedestrians). A slowed action will lead to a lower score.

Examples of scoring:

4 = Attends and responds to road signs, hazards and traffic in the road environment ahead.
3 = Hesitant in attending to and responding to road environment ahead.
2 = Late or slow in attending and responding to road environment ahead.
1 = Does not attend and respond to road environment ahead or needs intervention.

17. Attending and responding to the right

This item is about being able to attend the right side of the vehicle and then respond in a competent and safe manner. The right is defined as the area immediately to the right of the vehicle. This includes being able to attend and respond to stimuli in the traffic environment that is to the right of the vehicle, such as other vehicles, signs and pedestrians. It also includes ability to attend and act upon traffic in the blind spot. A slowed action will lead to a lower score.

Examples of scoring:

4 = Attends and responds to signs, traffic and hazards on the right of the vehicle
3 = Hesitant in attending and responding to stimuli on the right side of the vehicle.
2 = Late or slow in attending and responding to stimuli on the right side of the vehicle
1 = Does not attend and respond to stimuli on the right side of the vehicle or needs intervention.

18. Attending and responding to the left

This item is about being able heed to the left in a competent and safe manner, attending and responding to stimuli in the traffic environment that is to the left of the vehicle such as other vehicles, signs and pedestrians etc. Also ability to attend and act upon traffic in the left blind spot is scored. A slowed action will lead to a lower score.

Examples of scoring:

4 = Attends and responds to signs, traffic and hazards on the left side of the vehicle
3 = Hesitant in attending and responding to stimuli on the left side of the vehicle.
2 = Late or slow to attending and responding to stimuli on the left side of the vehicle.
1= Does not attend and respond to stimuli to the left side of the vehicle or needs intervention in it requires intervention.

19. Attending and responding to mirrors

This item is about being able to use mirrors to attend and respond to stimuli in the traffic environment to either side or the rear of the vehicle in a competent and safe manner. This includes awareness of other vehicles to the side/behind the vehicle and when changing lanes. A slowed action will lead to a lower score.

Examples of scoring:

4 = Actively uses mirrors to attend and respond to stimuli in the road environment such as other vehicles.
3 = Hesitant in using mirrors to attend and respond to stimuli to the side or rear of the vehicle.
2 = Does not use mirrors consistently or adequately to attend and respond to stimuli in the mirrors / to the side or rear of the vehicle so that there is potential for risk.
1= Does not use mirrors to respond to stimuli in the road environment. Example: Changing lanes increases risk of crash or requires intervention.

20. Attending and responding to regulatory signs

This item is about being able to attend and respond to signs of regulation in a competent and safe manner and appropriately following the intent of the signs. A slowed action will lead to a lower score.

Examples of scoring:

4 = Appropriately attends and responds to regulatory signs.
3 = Hesitate in attending or responding to regulatory signs
2 = Late in attend or respond to regulatory signs or corrects a mistake when made.
1 = Does not attend or respond to regulatory signs repeatedly or requires repeated cueing or intervention to avoid an adverse incident.

21. Attending and responding to advisory road signs

This item is about being able attend and respond to advisory signs in a competent and safe manner and appropriately responds to the intent of the advisory signs. A slowed action will lead to a lower score.

Examples of scoring:

4 = Attend and respond with the appropriate respond to advisory signs.
3 = Hesitant to attending and responding to advisory signs.
2 = Late in attending and responding to advisory signs or corrects a mistake when made.
1 = Does not attend or respond to advisory signs repeatedly or requires cueing or intervention to avoid an adverse incident.

22. Attends and responds to fellow road users

This item is about being aware of fellow road users and adjusting driving performance in a competent and safe manner as required. This includes being able to interact appropriately with fellow road users. A slowed action will lead to a lower score.

Examples of scoring:

4 = Attends and responds appropriately towards the intentions of fellow road users.
3 = Hesitant in attending and responding with fellow road users.

2 = Slowed or late in attending and responding to fellow road users.
1 = Does not attend or respond to fellow road users and requires intervention.

23. Reacting

This item is about being able to react in a timely manner and act appropriately to expected, unexpected, and hazardous road situations. A slowed action will lead to a lower score.

Examples of scoring:

4 = Reacts in advance to unexpected situations involving fellow road users or situations.
3 = Hesitant in response to unexpected situations in the road environment actions ore expected actions such as a red light.
2 = Late reaction to an unexpected action, but manages to respond appropriately to the situation.
1 = Does not react appropriately to an expected or unexpected action causing a risky situation and/or needing intervention.

24. Focusing

This item is about concentrating on the driving task in a competent and safe manner. This involves being able to focus on the task at hand and prioritize safety during driving. To be easily distracted leads to a lower score.

Examples of scoring:

4 = Concentrates on the driving task even with conversation.
3 = Increased hesitancy with maneuvers with any distraction, but able to complete the task. Example: Late in planning turn due to a conversation in the vehicle or can correct mistake without help.
2 = Late or misses maneuvers of the driving task with distractions. Example: Misses turn or signs during drive because talking instead of focusing on driving.
1 = Late or misses maneuvers of the driving task with distractions, is easily distracted, cannot correct mistakes, and needs intervention.

25. Problem solving

This item is about solving problems in a competent and safe manner without assistance.

Examples of scoring:

4 = Solves a problem or situation that arise during driving independently and adequately
3 = Hesitate in the solving of problems, but resolves the issue with little or no intervention.
2 = Late problem solving, requires prompting to solve problems.
1 = Unable to solve problems. Requires verbal or physical intervention.

Other:

Weather and road conditions: Note the circumstances for the test, for example slippery roads, rush hour or rain.

Standard route or special route: Specify which route was used. It is allowed to mark more than one.

General rules for scoring:

- Only score what you have observed.
- The worst behavior observed is scored; record and score error items even if the client has been driving well for the rest of the test.
- When you are hesitating between two scores, give the lower score.
- If an item has not been observed, do not score this item.
- When the car is adapted, do not give the client a lower score due to the adaption, but make sure that you have made a note about the modification on the score protocol.
- When you observe an error, it is usually scored down on several items.

Appendix G:
Demographic Questionnaire

1. What is your date of birth: ______________________________
2. What is your gender: _________________
3. How many years have you been driving independently: ____________
4. Do you self-report as having Autism Spectrum Disorder?: yes no

Appendix H:

Adolescent/Adult Sensory Profile

ADOLESCENT/ADULT SENSORY PROFILE™

Catana Brown, Ph.D., OTR, FAOTA
Winnie Dunn, Ph.D., OTR, FAOTA

Self Questionnaire

Name: ______________________ Age: __________ Date: __________

Birthdate: ______________________ Gender: ☐ Male ☐ Female

Are there aspects of daily life that are not satisfying to you? If yes, please explain. ______________________

____

____

____

INSTRUCTIONS

Please check the box that **best** describes the frequency with which you perform the following behaviors. If you are unable to comment because you have not experienced a particular situation, please draw an X through that item's number. Write any comments at the end of each section.

Please answer all of the statements. Use the following key to mark your responses:

ALMOST NEVER	When presented with the opportunity, you **almost never** respond in this manner (about 5% or less of the time).
SELDOM	When presented with the opportunity, you **seldom** respond in this manner (about 25% of the time).
OCCASIONALLY	When presented with the opportunity, you **occasionally** respond in this manner (about 50% of the time).
FREQUENTLY	When presented with the opportunity, you **frequently** respond in this manner (about 75% of the time).
ALMOST ALWAYS	When presented with the opportunity, you **almost always** respond in this manner (about 95% or more of the time).

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Item	A. Taste/Smell Processing	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
1	I leave or move to another section when I smell a strong odor in a store (for example, bath products, candles, perfumes).					
2	I add spice to my food.					
3	I don't smell things that other people say they smell.					
4	I enjoy being close to people who wear perfume or cologne.					
5	I only eat familiar foods.					
6	Many foods taste bland to me (in other words, food tastes plain or does not have a lot of flavor).					
7	I don't like strong tasting mints or candies (for example, hot/cinnamon or sour candy).					
8	I go over to smell fresh flowers when I see them.					

Comments

Item	B. Movement Processing	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
9	I'm afraid of heights.					
10	I enjoy how it feels to move about (for example, dancing, running).					
11	I avoid elevators and/or escalators because I dislike the movement.					
12	I trip or bump into things.					
13	I dislike the movement of riding in a car.					
14	I choose to engage in physical activities.					
15	I am unsure of footing when walking on stairs (for example, I trip, lose balance, and/or need to hold the rail).					
16	I become dizzy easily (for example, after bending over, getting up too fast).					

Comments

Item	C. Visual Processing	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
17	I like to go to places that have bright lights and that are colorful.					
18	I keep the shades down during the day when I am at home.					
19	I like to wear colorful clothing.					
20	I become frustrated when trying to find something in a crowded drawer or messy room.					
21	I miss the street, building, or room signs when trying to go somewhere new.					
22	I am bothered by unsteady or fast moving visual images in movies or TV.					
23	I don't notice when people come into the room.					
24	I choose to shop in smaller stores because I'm overwhelmed in large stores.					
25	I become bothered when I see lots of movement around me (for example, at a busy mall, parade, carnival).					
26	I limit distractions when I am working (for example, I close the door, or turn off the TV).					

Comments

Item	D. Touch Processing	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
27	I dislike having my back rubbed.					
28	I like how it feels to get my hair cut.					
29	I avoid or wear gloves during activities that will make my hands messy.					
30	I touch others when I'm talking (for example, I put my hand on their shoulder or shake their hands).					
31	I am bothered by the feeling in my mouth when I wake up in the morning.					
32	I like to go barefoot.					
33	I'm uncomfortable wearing certain fabrics (for example, wool, silk, corduroy, tags in clothing).					
34	I don't like particular food textures (for example, peaches with skin, applesauce, cottage cheese, chunky peanut butter).					
35	I move away when others get too close to me.					
36	I don't seem to notice when my face or hands are dirty.					
37	I get scrapes or bruises but don't remember how I got them.					
38	I avoid standing in lines or standing close to other people because I don't like to get too close to others.					
39	I don't seem to notice when someone touches my arm or back.					

Comments

Item	E. Activity Level	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
40	I work on two or more tasks at the same time.					
41	It takes me more time than other people to wake up in the morning.					
42	I do things on the spur of the moment (in other words, I do things without making a plan ahead of time).					
43	I find time to get away from my busy life and spend time by myself.					
44	I seem slower than others when trying to follow an activity or task.					
45	I don't get jokes as quickly as others.					
46	I stay away from crowds.					
47	I find activities to perform in front of others (for example, music, sports, acting, public speaking, and answering questions in class).					
48	I find it hard to concentrate for the whole time when sitting in a long class or a meeting.					
49	I avoid situations where unexpected things might happen (for example, going to unfamiliar places or being around people I don't know).					

Comments

Item	F. Auditory Processing	ALMOST NEVER	SELDOM	OCCASIONALLY	FREQUENTLY	ALMOST ALWAYS
50	I hum, whistle, sing, or make other noises.					
51	I startle easily at unexpected or loud noises (for example, vacuum cleaner, dog barking, telephone ringing).					
52	I have trouble following what people are saying when they talk fast or about unfamiliar topics.					
53	I leave the room when others are watching TV, or I ask them to turn it down.					
54	I am distracted if there is a lot of noise around.					
55	I don't notice when my name is called.					
56	I use strategies to drown out sound (for example, close the door, cover my ears, wear ear plugs).					
57	I stay away from noisy settings.					
58	I like to attend events with a lot of music.					
59	I have to ask people to repeat things.					
60	I find it difficult to work with background noise (for example, fan, radio).					

Comments

Summary Score Sheet

Quadrant Grid

Instructions: Transfer from the *Self Questionnaire* the item raw score that corresponds with each item listed (refer to the *User's Manual* for directions on how to obtain item raw scores). Add the Raw Score column to get the Quadrant Raw Score Total for each quadrant.

QUADRANT 1		QUADRANT 2		QUADRANT 3		QUADRANT 4	
Low Registration		Sensation Seeking		Sensory Sensitivity		Sensation Avoiding	
Item	Raw Score	Item	Raw Score	Item	Raw Score	Item	Raw Score
3		2		7		1	
6		4		9		5	
12		8		13		11	
15		10		16		18	
21		14		20		24	
23		17		22		26	
36		19		25		29	
37		28		27		35	
39		30		31		38	
41		32		33		43	
44		40		34		46	
45		42		48		49	
52		47		51		53	
55		50		54		56	
59		58		60		57	
Quadrant Raw Score Total		Quadrant Raw Score Total		Quadrant Raw Score Total		Quadrant Raw Score Total	

SCORE KEY	
1	Almost Never
2	Seldom
3	Occasionally
4	Frequently
5	Almost Always

ICON KEY
Low Registration
Sensation Seeking
Sensory Sensitivity
Sensation Avoiding

Quadrant Summary

Instructions: Choose the appropriate Quadrant Summary Chart and then transfer the Quadrant Raw Score Total from the previous page to the corresponding Quadrant Raw Score Total box. Plot these totals by marking an X in the appropriate classification column (Much Less than Most People, Less than Most People, etc.).*

Quadrant Summary Chart for Ages 11–17

Quadrant	Quadrant Raw Score Total	Much Less Than Most People	Less Than Most People	Similar To Most People	More Than Most People	Much More Than Most People
		− −	−	=	+	+ +
1. Low Registration	/75	15 — 18	19 — 26	27 — 40	41 — 51	52 — 75
2. Sensation Seeking	/75	15 — 27	28 — 41	42 — 58	59 — 65	66 — 75
3. Sensory Sensitivity	/75	15 — 19	20 — 25	26 — 40	41 — 48	49 — 75
4. Sensation Avoiding	/75	15 — 18	19 — 25	26 — 40	41 — 48	49 — 75

*Classifications are based on the performance of individuals without disabilities ($n = 193$).

Quadrant Summary Chart for Ages 18–64

Quadrant	Quadrant Raw Score Total	Much Less Than Most People	Less Than Most People	Similar To Most People	More Than Most People	Much More Than Most People
		− −	−	=	+	+ +
1. Low Registration	/75	15 — 18	19 — 23	24 — 35	36 — 44	45 — 75
2. Sensation Seeking	/75	15 — 35	36 — 42	43 — 56	57 — 62	63 — 75
3. Sensory Sensitivity	/75	15 — 18	19 — 25	26 — 41	42 — 48	49 — 75
4. Sensation Avoiding	/75	15 — 19	20 — 26	27 — 41	42 — 49	50 — 75

*Classifications are based on the performance of individuals without disabilities ($n = 496$).

Quadrant Summary Chart for Ages 65 and older

Quadrant	Quadrant Raw Score Total	Much Less Than Most People	Less Than Most People	Similar To Most People	More Than Most People	Much More Than Most People
		− −	−	=	+	+ +
1. Low Registration	/75	15 — 19	20 — 26	27 — 40	41 — 51	52 — 75
2. Sensation Seeking	/75	15 — 28	29 — 39	40 — 52	53 — 63	64 — 75
3. Sensory Sensitivity	/75	15 — 18	19 — 25	26 — 41	42 — 48	49 — 75
4. Sensation Avoiding	/75	15 — 18	19 — 25	26 — 42	43 — 49	50 — 75

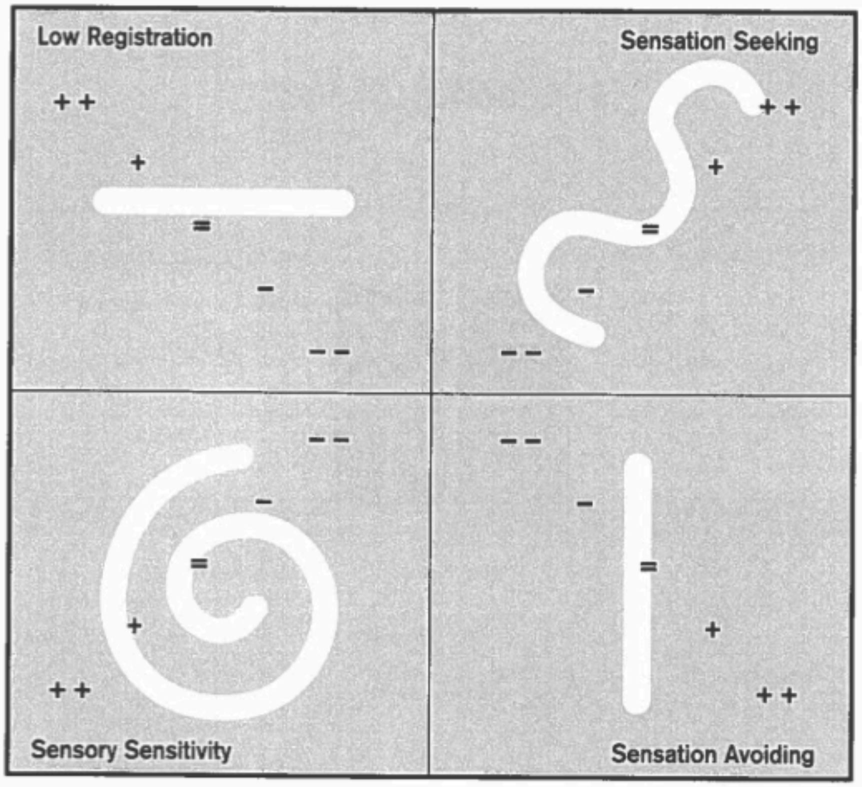
*Classifications are based on the performance of individuals without disabilities ($n = 261$).

Quadrant Profile

Instructions: Transfer the information from the classification columns of the Quadrant Summary Chart (the areas marked with an X) to the Quadrant Profile. Circle the classification symbol in each quadrant below that corresponds with the classification information for that quadrant. Finally, check the appropriate age box.

The following symbols are used to represent the classifications on the Quadrant Profile:

- – – Much Less Than Most People
- – Less Than Most People
- = Similar to Most People
- + More Than Most People
- + + Much More Than Most People



See chapter 5 for more information regarding interpretations and intervention.

Check the correct age:

- ☐ 11–17 years
- ☐ 18–64 years
- ☐ 65 years and older