

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

by

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Major Department: Occupational Therapy

Purpose: Driving is an important step in attaining independence for teens and young adults as it allows for an independent mode of transportation for the development of social relationships and expansion of employment opportunities. Music and background chatter are common auditory stimulators that may improve or hinder driving performance. This pilot study investigated the effects of background music on the driving performance of individuals with Autism Spectrum Disorder (ASD) as compared with neurotypical individuals to identify how the environment can best be modulated to facilitate safe driving. **Design:** A quasi-experimental 2 (ASD/not ASD) X 3 (music condition: no music, light classical, and self-selected) factorial design was used. **Method:** Participants consisted of 33 adolescents and young adults; one group with ASD (n=18) and a control group of neurotypical individuals (n=15). All the participants were observed under the three conditions driving similar 15-minute scenarios with critical events on a driving simulator route. The dependent variable was driving performance, measured by a quantitative score from a standardized observational tool for driving, the Performance Analysis of Driving Ability (P-Drive). The learning curve was considered a covariate. **Results:** Repeated measures ANOVA showed no difference in driving performance among young drivers with ASD when compared across music conditions ($p=0.275$). While it is a small sample using a

simulator, the results suggest that background music will not assist or impair with driving performance. Additionally, there was no difference overall between the two groups of drivers, ASD and neurotypical ($p=.292$). There was a significant effect of order and driving experience level, so these were controlled for throughout the analysis. **Conclusion:** While there was no difference in driving performance overall between the three music conditions, there are still key implications for practice. It may suggest background music playing may not hinder driving performance providing contesting evidence against the common assumption that music is a distraction while driving.

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Chapter 1: Introduction

In occupational therapy, emphasis is placed on independence and helping clients improve their abilities to successfully carry out meaningful tasks (American Occupational Therapy Association [AOTA], 2014). One area of daily living that is especially important in achieving a sense of independence is driving and community mobility (AOTA, 2014). Driving is an important first step in attaining independence and developing work and social relationships, as it provides people with an independent mode of transportation to do as they please and go where they please (Monahan, 2012). Accordingly, there is a need for research emphasis to be placed on increasing knowledge regarding the conditions that make vehicles productive environments for facilitating safe driving.

Music, radio stations, and the chatter of passengers are common background sounds while driving, but there is varying research on the impacts of these sounds on safe driving for young adults (Unal, de Waard, Epstude, & Steg, 2013; van der Zwaag, Janssen, Nass, Westerink, Chowdhury, & de Waard, 2013). For example, one study found that music positively affected driving performance relating to lane-keeping and faster response time (Unal et al., 2013), while another study indicated that fast tempo music is a known cause of driving errors (van der Zwaag et al., 2013). Very little can be done to control the environment outside of the car. However, something can be done to control the environment inside the car. If it is known how to best control the vehicle environment to allow for safe driving, then people may be able to demonstrate safer driving and thus achieve independence through successfully performing the daily activity of driving and community mobility (AOTA, 2014).

While driving is an essential activity intertwined into many daily lives, it can come with negative outcomes, especially among young drivers. Drivers ages 16-17 continue to have the

highest rates of crash involvement, injuries to themselves and others, and deaths of others in crashes where they are involved, followed by those ages 18-19 and 20-24 (Teft, 2017).

Furthermore, as the prevalence of ASD increases, so too does the prevalence of teenagers with ASD (Centers for Disease Control and Prevention [CDC], 2016). It is therefore applicable and relevant for teenagers and young adults with ASD to be included in the group of young drivers needing immediate attention towards efforts that address environmental factors contributing to driving performance. There needs to be a focus on investigating ways to reduce these crash statistics and create safer driving among teens and young adults. With a constant need for driving intervention and an increasing prevalence of ASD, it is imperative that measures be taken to investigate strategies for enhancing driving performance and mitigating crash risk. As driving is an instrumental activity of daily living, addressing this concern is therefore within the purview of occupational therapy practice.

Chapter 2: Literature Review

Driving as an IADL

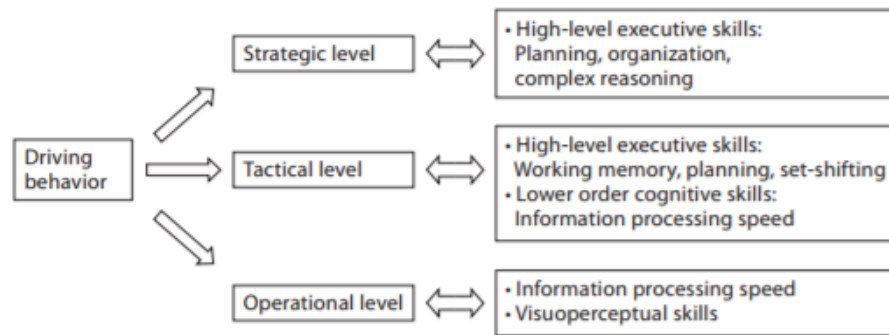
Occupational therapy can be defined as the therapeutic use of everyday life activities to enhance or enable participation in roles, habits, and routines (AOTA, 2014). These everyday activities, or occupations, include activities of daily living (ADLs), instrumental activities of daily living (IADLs), rest and sleep, education, work, play, leisure, and social participation (AOTA, 2014) with ADLs and IADLs being the mainstay of occupational therapy practice (Doucet, 2014). Driving and community mobility, as an IADL, is one of many everyday life activities that can enable one's participation in roles and routines, allowing for the feeling of living a satisfying and meaningful life.

Since driving is an IADL and considered to be an important first step in attaining independence in work, school, and/or social participation (AOTA, 2014; Monahan, 2012), it is then important for occupational therapy practitioners to address driving. There is even an option for occupational therapists to specialize in the practice of driving rehabilitation in order to develop and implement driving rehabilitation for individuals with disabilities as well as evaluate driving skills (Dickerson & Davis, 2012; Classen, Monahan, & Wang, 2013). It is therefore fitting for occupational therapy research to address the driving difficulties that clients experience.

Driving Demands

Driving is a complex activity that requires a variety of cognitive, visual, perceptual, and motor skills. In most driving situations, the driver must use visual-perceptual skills, process information, make a decision on how to react, and carry out the motor actions associated with their reaction plan. Michon et al. (1985) created a driving model to better explain the driving skills required for this high-level task (see Figure 1).

Figure 1. Michon's Model and Cognitive Functions Involved in Driving.



Michon outlines three key domains of cognitive skills needed for the complex task of driving: 1) operational, 2) tactical, and 3) strategic (see Figure 1). At the operational level, drivers must have skills in vision and perception as well as information processing. The tactical level requires that drivers have similar skills to those required at the operational level in addition to executive function skills that include working memory and planning. The highest level of driving behavior is the strategic level at which drivers must demonstrate effective executive functioning in planning, organizing, and complex reasoning. The always-changing, dynamic driving environment challenges drivers to excel in information-processing, action planning, and reacting for the duration of the drive. Michon's model is relevant to teens and young adults because it outlines essential skills required for driving and allows for the opportunity to improve those skills with the intentional therapeutic use of background music.

Other notable driving demands include divided attention, selective attention, visual-motor integration, cognition, complex sequencing, visual scanning, identifying roadway hazards, speed regulation, lane maintenance, adjustment to stimuli, motor planning, multitasking, concentration, understanding nonverbal communication, generalizing information, tolerating unexpected changes in routine, and tolerating others' violation of rules (Classen et al. 2013; Cox, Reeve, Cox, & Cox, 2012).

Driving Demands and Teens

Typically, when teens near the driving age, there is much excitement about getting a driver's license and being able to drive a car. However, it is widely recognized that the earliest stages of independent driving are associated with the greatest risk (Scott-Parker, 2015).

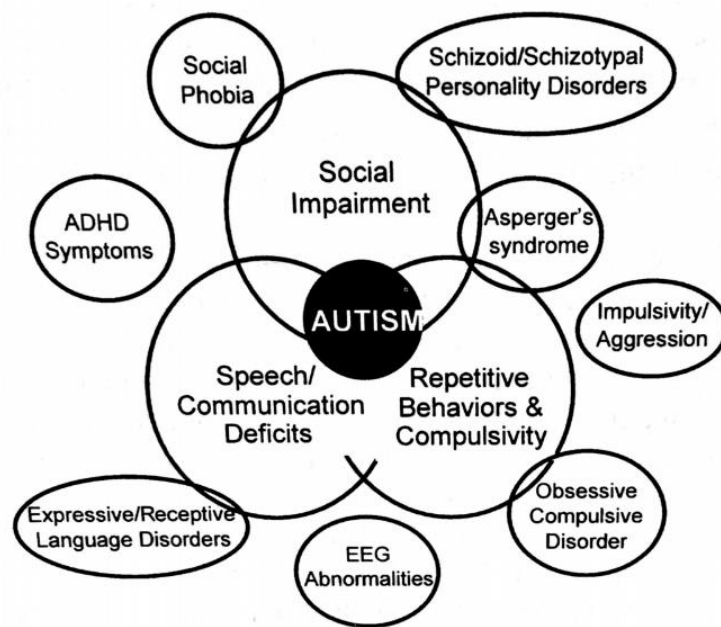
Considering the high crash risk of early independent driving, it is important to understand the demands of driving and how risk can be reduced. One study comparing crash risk between novice and experienced drivers found that novice drivers demonstrated increased crash risk from secondary tasks such as texting and dialing cell phones, reaching for a cell phone, looking at roadside objects, or eating (Klauer et al., 2014). All of these secondary tasks require the driver to look away from the road ahead and therefore create situations when the driver is not attending to the road environment and task at hand (Klauer et al, 2014). Novice drivers should reduce their engagement in secondary tasks to aide in maintaining focus on the road and reducing crash risk. These considerations indicate that novice teen drivers should have strong cognitive skills in sustained attention and limited distractibility. Other demands of driving include multi-tasking, identifying hazards, and quick reaction time (Reimer et al, 2013), so teens must have strong skillsets in these areas as well.

Autism Spectrum Disorder

Every 1 in 68 children in the United States are diagnosed with ASD, and that number continues to climb (CDC, 2016). Hollander and Nowinski (2003) have conceptualized ASD as being categorized by three primary domains in which individuals have difficulty: 1) social impairment, 2) speech/communication deficits, and 3) repetitive behaviors and compulsivity (see Figure 2). Under the social domain, individuals may have impairments in non-verbal behaviors such as aversion of eye-to-eye gaze, inappropriate body postures and gestures, and difficulty

recognizing verbal and nonverbal cues. For communication, individuals may have impairments in ability to sustain a conversation, and they may only use nonverbal communication. However, communication is typically not impaired, nor as significantly, in individuals with high-level autism or Asperger's syndrome and will likely not be an area of difficulty affecting driving. Under the repetitive behaviors/compulsivity domain, individuals may have impairments in being preoccupied, becoming agitated when there are sudden changes, or engaging in repetitive behaviors such as tapping, rubbing, and rocking. Considering this conceptualization of ASD, it is possible and likely that, under the stress of driving and its associated demands, individuals may engage in distracting behavior which may threaten their driving performance. Many individuals with ASD have sensory processing impairments, which can further contribute to their areas of difficulty in responding to the environment (Rodger & Ziviani, 2012).

Figure 2. Diagram of the Three Core Deficits that Characterize ASD: 1) social impairment, 2) speech/communication deficits, and 3) repetitive behaviors and compulsivity (Hollander & Nowinski, 2003).



ASD individuals often engage in repetitive behaviors that have the potential to interfere with many aspects of life including school, work, and social life (CDC, 2016; Lundy-Ekman, 2013). In addition, several social deficits that characterize the disorder as well as compulsive behaviors (Hollander & Nowinski, 2003) may impede attaining a license. Thus, it is important to understand these characteristics of ASD and the impact they have on driving.

Autism and Driving

It is especially important to consider the impact that the environment has on individuals with Autism Spectrum Disorder (ASD), because individuals within the Autism Spectrum tend to be more sensitive to the stimulators in their environment (Lundy-Ekman, 2013). Estimates from the late 1900s suggest that 42-88% of individuals with autism have unusual sensory responses (Kientz & Dunn, 1997; Volkmar, Cohen, & Paul, 1986), while a more recent estimate indicates that up to 95% of individuals with ASD experience sensory processing impairment (Tomcheck & Dunn, 2007). The environment inherently provides sensory input, which may cause overresponsivity or underresponsivity in individuals with ASD (Rodger & Ziviani, 2012). Sensory system impairment can negatively affect an individual's behavioral response to his or her situation (Rodger & Ziviani, 2012). Sudden or abrupt changes in behavior as a result of sensory processing impairment can create dangerous driving situations, so it is important to modulate the environment to facilitate the IADL of driving and community mobility in individuals with ASD. Given the many environmental factors at play during driving (e.g. weather, traffic, road condition, number of passengers in the vehicle, and emergency vehicles), it is critical that research be done to indicate what environmental conditions create the optimal driving experience.

With the growing prevalence of ASD, there is a growing prevalence of individuals with ASD reaching driving age and getting out on the road. With impairments ranging from sensory to attention, there may be significant barriers that prevent individuals with ASD from attaining a level of acceptable driving performance.

Since individuals with ASD have been shown in some instances to perform worse than healthy controls, it is important to have a better understanding of their specific driving difficulties so as to target those difficulties in driving training programs to improve driving skills (Sheppard, Ropar, Underwood, & van Loon, 2010; Reimer et al., 2013; Cox et al. 2016; Classen et al., 2013). One survey done in New Jersey looked at the needs of their adult autistic population and found that 24 percent of adults with autism were independent drivers, whereas 75 percent of the population as a whole were independent drivers (Freeley, 2010). With such a comparably small percentage of individuals with autism driving independently, it is important to develop driving interventions and strategies that address areas of need to strengthen driving performance and increase the number of successful independent individuals driving with autism (Reimer et al., 2013; Classen et al., 2013). The demands of driving paired with areas of difficulty for individuals with ASD help to explain why driving can be a challenge.

Existing literature continues to comment on the paucity of research on driving and individuals with ASD (Classen et al., 2013; Cox et al. 2012). With driving demands including several skills that come as a challenge to many individuals with ASD, more research is needed to pinpoint the optimal conditions needed for driving to be a successful endeavor.

Environment

Occupational therapy emphasizes consideration of the environment in which occupations occur because it is known that the environment can affect occupational participation and

performance (AOTA, 2014). It follows, then, that driving as an IADL is likely influenced by environmental factors, because driving is an occupation that requires successful and safe performance for optimal participation and client independence. Some environmental factors that occupational therapy considers are physical, social, temporal, and virtual (AOTA, 2014). In the context of driving, physical factors include the road, road signs, other cars, and construction zones. Social factors include other passengers in the car and pedestrians on the road. Temporal factors include the time of day, such as rush hour. Virtual factors can apply to driving performance using a driving simulator. Taken altogether, it is apparent that the environment possesses many components that have the potential to impact driving. While many factors from the driving environment cannot be controlled, the social and auditory environment is a factor that can be controlled and modulated by the driver or passenger in the form of strategically limiting background chatter or selecting certain music/radio stations known to facilitate good driving. As it is common for individuals to play music, listen to the radio, and speak on the phone, it is important to evaluate this factor on teen/young adult drivers as well as those with ASD.

Music's Effect on Attention and Concentration

Huang and Shih (2011) conducted a pilot study on the effects of different types of background music on listener concentration. The study utilized a randomized control trial, where 89 participants between the ages of 19 and 28 years old were randomly divided into four groups. Each group was assigned a music condition (e.g. popular music, classical light music, and traditional Chinese music), and it was under this condition that participants were administered the *Chu's Attention Test* (Chu, 2001). *Chu's Attention Test* is a standardized evaluation tool used in China to predict attention level. The test consists of over 100 questions that require the participant to search for the “*” sign among a series of scrambled codes. The

participants answered as many questions as they could in one minute, and the total score was obtained by subtracting the number of incorrect answers from the total number of answers. After completion of *Chu's Attention Test*, participants rated their liking of the background music on a Likert Scale ranging from 1 (strongly dislike) to 5 (strongly like).

It was found that participants with exposure to background music tended to perform worse than participants without exposure. However, an analysis of variance (ANOVA) showed that there was no significant difference between the groups on their *Chu's Attention Test* results. Within each group, participants rated their level of liking for the background music. It was found that if the listener either strongly liked or strongly disliked the music, then their attention was negatively impacted and they produced significantly lower test scores than participants in a quiet environment. The researchers hypothesized that this occurs because people tend to pay more attention to music that they strongly like or strongly dislike. Huang and Shih (2011) also used a theory of Occupational Form and Occupational Performance to explain why background music should influence attention test scores. The theory posits that occupational performance changes with occupational form (Nelson, 1988). Music can be considered as its own occupational form, and therefore has the potential to influence attention as the occupational performance. The study recommended that neutral music be selected as optimal background music to avoid strong like or dislike on the part of the listener, helping to facilitate optimal attention to the task at hand (Huang & Shih, 2011).

A different study by Shih, Huang, and Chiang (2012) explored how background music with and without lyrics affects young worker attention performance. Researchers conducted a randomized control trial using 102 participants between ages 20 and 24 years old. Participants were randomly assigned to two groups; one group received music with lyrics as their stimulus,

and the other group received music without lyrics as their stimulus. The *Chu Attention Test* was administered for 10 minutes both as a baseline without music and three weeks later while listening to music to evaluate participants' task attention. Similar to Huang and Shih (2011), Shih et al. (2012) also used the theory of Occupational Form and Occupational Performance to suggest how background music might affect attention. Translating this concept to the work environment, worker attention performance (occupational performance) would change with background music (occupational form).

When comparing the two different groups (background music with and without lyrics) against each other on *Chu Attention Test* attention scores, there was no significant difference between the groups. The music without lyrics group decreased on their *Chu Attention Test* scores between the baseline and the treatment condition, although this difference was not significant. However, the music with lyrics group significantly decreased on their *Chu Attention Test* scores between the baseline and the treatment. Thus, background music with lyrics negatively affected performance. Because music with lyrics had a significantly negative effect on concentration and attention, music without lyrics was listed as the preferred choice in background music for the workplace (Shih et al., 2012).

Music in Classroom

In another study, Chou (2010) evaluated the effects of classical and hip-hop music on the concentration of Taiwanese college students. The study was guided in part by the capacity model of attention. The capacity model of attention suggests several concepts: 1) there are a limited amount of resources in someone's mental capacity for processing, 2) how well a person concentrates may depend on the amount of attention that the person devotes to the task, 3) attention can increase or decrease based on the arousal level of the activity, and 4) performance

fails when the supply of attention does not meet the activity demands (Kahneman, 1973).

Having background music present could affect participant concentration by taking away some of the attention needed for the task at hand. It is believed, however, that the right kind of music can reduce stress of students and improve their productivity (Hallman & Price, 1998). For example, previous research has shown that Mozart classical music improved student test performance (Cockerton, Moore, & Norman, 1997; Rauscher, Shaw, & Ky, 1993). Chou (2010) therefore looked at two primary research questions considering the how the presence of music and the type of music can affect student concentration. The research questions were 1) Does listening to music effect learner concentration when doing a reading task, and 2) Is light classical music more distracting or less distracting than hip-hop music during a reading comprehension task (Chou, 2010).

Participants were students (N=133) between the ages of early 20's to mid 50's who were recruited from the English department of a college in Taiwan. Participants were randomly assigned to either the control group with no background music, a group with light classical background music, or the treatment group with hip hop background music. Participants were administered a Test of English as a Foreign Language (TOEFL) task where they were asked to complete three reading passages and answer 30 reading comprehension questions within a 35-minute time frame while their respective background music played at a noticeable volume. The TOEFL assessment was scored for accurate answers to the 30 reading comprehension questions (Chou, 2010).

Results showed that there was a significant difference in the performance of the reading comprehension task due to the different types of background music. The control group performed better than both hip-hop and classical music groups, but there was only a significant

difference with the hip-hop background music. In terms of the two music groups, the light classical had higher test scores than the hip-hop, but there was no significant difference between the two groups. Thus, the researchers concluded that music was found to be a distraction to concentration and task performance using the limited capacity theory to explain the outcomes. Participants were told to ignore the background music, so the distraction from successfully completing the reading comprehension task may have occurred because attention was unconsciously being drained from the participants by the background music with the hip-hop “draining” more of the attention. This concept was named the attention drainage effect (Chou, 2010).

In a related study, Anders (2011) conducted a comprehensive search of the literature to explore the effects of classical background music on behavior in elementary school children. Some cases showed that music therapy improved concentration and aggressive behaviors (Herman, 1996; De Mers, Tincani, Van Norman, & Higgins, 2009). Anders (2011) concluded that music had been shown to be an effective way of managing a person’s mind, body, and mood. This evidence supports the use of classical music as a selection for background music for doing demanding activities because classical music has potential to improve concentration and behavior (Anders, 2011), which may have implications on driving performance, as concentration is a key demand of driving (Cox et al., 2012).

Music and Individuals with ASD

For many years, music therapy has been a technique used to treat individuals with ASD with varying degrees of success. Music is believed to be a facilitating tool that can help children with ASD in areas of play and socialization, as it does not require verbal interaction (Warwick, 1991). In fact, in a recent study, Preis, Amon, Robinette, and Rozegar (2016) examined the

effects of background music on children with autism during play. They conducted a preliminary study using five males with ASD ages four to six. A single-subject alternating treatments design was used to assess participants under two conditions (no music and background music). During each condition, participants' expressive language and engagement was quantified by the number of spontaneous utterances and number of disengagements. Data was collected during a 30-minute period of structured play, 15 minutes of which was the no-music condition and 15 minutes of the music condition. The type of background music was randomized between classical, children's, and reggae music for the first 12 weeks of the study; background music was non-randomized for the remaining 16 weeks of the study, as classical and children's music were chosen for 8 weeks at a time. Music was set a decibel level consistent with typical classroom music levels. Participants were neither encouraged nor discouraged from attending to the music.

Using the mean (M) and standard deviation (SD) for the number of spontaneous utterances and number of disengagements, researchers compared findings between groups. The number of spontaneous utterances was higher during the children's and classical music conditions as compared to their balanced non-music conditions. The number of disengagements was lower in the music conditions than the non-music conditions, although the difference was very small. Participants were slightly more engaged in the classical and reggae genres as compared to the non-music conditions. Results showed overall that there was little to no effect of background music of any type (classical, children's songs, or reggae) on verbal expression or engagement in children with ASD during play, and the type of music played did not significantly affect outcomes (Preis et al., 2016). However, the age of these children was four to six years old, and the degree of concentration needed for driving may be much different than the degree of concentration needed for play.

Music and Driving

A 2012 study examined the effects of music on mental effort and driving performance (Unal, Steg, & Epstude). They hypothesized that 1) music would induce extra mental effort while driving as compared to drivers who do not listen to music, irrespective of the complexity of the traffic situation, and 2) drivers who listened to music would perform as well as or even better than drivers who do not listen to music, and 3) any difference in performance levels between drivers in music and non-music conditions would be mediated by mental effort.

Participants were 74 psychology students with an age range of 18-31 years who had valid driving licenses. The study used between-group design with a music and no-music condition. Participants in the music condition created their own playlists from a website of songs and genres to increase the ecological validity, as participants chose music with which they were familiar. The driving task involved nine hazardous events in a mix of residential and rural settings. Driving performance indicators were brake response to hazardous events, maximum deceleration during the incidents, time-headway to the lead car, time-to-contact with the lead car, lateral positioning, and speed. Mental effort was measured through self-report on the *Rating Scale of Mental Effort* (Zijlstra, 1993).

Results showed that listening to loud music increased mental effort while driving, supporting the assumption that music is distracting while driving. However, music did not impair driving performance, and in two driving situations music improved driving performance. Researchers drew the conclusion that mental effort might mediate the effect of music on driving performance (Unal et al., 2012).

A 2013 study examined the effects of music on driving performance, arousal level, and mental effort while performing a monotonous car-following task (Unal, de Waard, Epstude, &

Steg). The researchers hypothesized that 1) listening to music would either have no effect or a positive effect on performance of a monotonous car-following task, 2) the arousal level of participants, as measured by self-report and mean heart rate, would be higher when listening to music while performing the monotonous car-following task, and 3) mental effort, as measured by heart-rate variability, would be higher in the absence of music than in the presence of music.

The 47 participants in this study had an age range of 19-25 years old and were all college psychology majors. The study used a 2 (driving with and without music) X 2 (loudness: listening to loud or moderate volume music) mixed-subjects design. Participants used a driving simulator, and the order of the experimental (music) and control (no music) conditions was counterbalanced. The same 30-minute driving route was used for the monotonous, low complexity, car-following task. To avoid potential learning affects, there was at least a 2-week interval between the first and second assessments of the participants. For the experimental condition, participants created their own playlist from an online music library to ensure high familiarity with and liking of the music. To measure driving performance, the delay in response was measured to reflect how accurately the participant adjusted to and maintained the speed of the lead vehicle. Participant lateral control, or lane position, was also assessed using the standard deviation of lateral position (SDLP). An electrocardiogram (ECG) was used to measure participant's mean heart rate and heart-rate variability to indicate level of arousal and amount of mental effort, respectively.

Results supported the first hypothesis that the presence of music did not have an effect on car-following performance (Unal et al., 2013). There was a significant main effect of the presence of music in all parts of the car-following task. For example, participants responded faster to the speed changes of the lead car when they listened to music while driving than when

there was no music. Participants also had a smaller SDLP when driving with music as compared to no music. Participants even reported being more aroused after driving with music. The study found overall that listening to music correlates with increased arousal, which could translate to improved driving performance (Unal et al., 2013). If increased arousal does translate to improved driving performance, then music can be utilized as an intentional tool to arouse and alert the driver, hone concentration, and optimize driving skill.

Self-Selected Music Effects on Task Performance

Cassidy and MacDonald (2009) conducted a between-subjects study comparing the effects of self-selected music and experimenter-selected music on activity performance and experience during a video driving game. The 125 participants had an age range of 18-25 years, and they were assigned to one of five background sound conditions to listen to while completing three trials of the video game. Background sound conditions were car sounds, silence, low-arousal music (i.e. 70 beats per minute—bpm), high-arousal music (i.e. 130 bpm), and self-selected music. The performance measures taken included 1) accuracy (i.e. collisions), 2) time (i.e. ms—minutes and seconds), and 3) speed (i.e. mph—miles per hour). Inaccuracy was measured by recording one mark each time the player collided with a cone or surrounding barrier of the driving course and finding the average of the three trials. Mean lap time (ms) and mean lap speed (mph) were calculated from the three trials as well. The experience measures taken were distraction, liking, appropriateness, enjoyment, and tension-anxiety. Participants responded to a *Profile of Mood States* (POMS) (McNair et al., 1971) brief questionnaire before and after the video game task to assess the experience measures and any changes that may have occurred.

Results indicated that there was a statistically significant effect of sound conditions on the dependent variables. It was found that when participants self-selected their music, they were

most efficient, had perceived lowest distraction, showed highest enjoyment, and experienced a reduction in tension-anxiety. High arousal music yielded greatest inaccuracy and therefore required more processing resources than other sound conditions. Self-selected music did not affect accuracy, suggesting that self-selected music is less of a threat to the limited processing resources of participants. Researchers assert that self-selected music resulted in increased emotional and attentional engagement due to increased arousal levels. The findings overall demonstrate the efficacy of self-selected music as a tool to optimize performance in everyday activities (Cassidy & MacDonald, 2009). Because personalization of music is also appropriate in the context of simulator driving and on-road driving, it can be hypothesized that self-selected music will have a similar impact on characteristics that affect driving performance, including arousal, distraction, and anxiety.

Summary

Driving independence matters to occupational therapy practitioners because it is a direct way to provide clients with the tools and resources needed to live a fulfilling, successful, and autonomous life. Existing literature explains how music can be a useful tool in improving concentration and performance in the classroom as well as increasing arousal level and accuracy during a video game driving task (Anders, 2011; Hallman & Price, 1998; Cockerton et al., 1997; Rauscher et al., 1993; Cassidy & MacDonald, 2009). This finding is controversial, however, as other literature has shown that music can be a distraction to concentration and task performance (Chou, 2010; Unal et al., 2012). The studies overall indicate that non-lyrical, neutral classical music may be the best selection for background music, so light classical music will be used as an experimental music condition for the present study. It also appears that enjoyable, self-selected

music may affect an individual's attention and interest to the task at hand, so self-selected music will be used as another experimental music conditions.

The literature addresses key topics of interest including background music, driving performance, ASD, and classroom concentration and test performance. However, there is a gap in the literature that has created the need to examine the effects of background music on driving performance in individuals with ASD. Individuals with ASD have difficulties in several areas that directly relate to demands of driving (Hollander & Nowinski, 2003; Rodger & Ziviani, 2012; Classen et al., 2013; Cox et al., 2012), and neurotypical individuals have been shown to demonstrate a decrease in driving performance under certain music conditions (van der Zwaag et al., 2011). It is critical to both the ASD and neurotypical populations to look for ways to improve safe and effective driving. Thus, the purpose of this pilot study was to investigate the effects of background music on the driving performance of ASD individuals as compared with neurotypical individuals. The first hypothesis is that neurotypical group will show better driving performance compared to the ASD group. The second hypothesis is that music will affect driving performance in both the neurotypical group and ASD group.

Chapter 3: Methods

Design

A quasi-experimental 2 (ASD/not ASD) X 3 (music condition: no music, light classical, and self-selected) factorial design was used in the present study. There were two groups, one with individuals with ASD (n=16) and the other with neurotypical individuals who do not have a diagnosis indicating neurological impairment or delay (n=16). Each group participated in three driving scenarios on a driving simulator. For each driving scenario, there was a different music condition (manipulated independent variable) that either consisted of 1) no background music, 2) light classical background music, or 3) self-selected background music. The music conditions were counterbalanced to control for any order effect. The order of driving scenarios remained the same for all participants so that any learning that occurred was the same. The dependent variable of driving performance was measured by a quantitative score of a standardized observational tool for driving.

Participants

Participants were recruited using convenience and snowball sampling methods. Advertisements were sent out to East Carolina University (ECU), the Greenville Treatment and Education of Autistic and Related Communication Handicapped Children center, local high schools, and local church youth groups. A questionnaire was used to determine participant eligibility based on inclusion and exclusion criteria (see Appendix A). Inclusion criteria for ASD participants included a current diagnosis of ASD and either completion of a driver's education course or eight to ten hours of experience using the driving simulator. Exclusion criteria for ASD participants included uncorrected vision impairments and older than 30 years of age. Inclusion criteria for neurotypical participants included either completion of a driver's

education course or eight to ten hours of experience using the driving simulator. Exclusion criteria for neurotypical participants included a diagnosis of any neurological or developmental disorder, uncorrected vision impairments, and older than 30 years of age.

All approved participants signed a consent form approved by ECU's Institutional Review Board (IRB) (see Appendix B). The principal investigator (PI) determined if the individual was eligible to start the study. Eligible participants included individuals who had completed driver's education. If the participant did not have experience with the simulator and had not completed driver's education, the participant completed 8-10 hours of experience with the driving simulator before beginning the study.

Participant demographics were attained to compare groups (see Table 1). The autism group contained participants with ages ranging from 14-25 (mean=17.7, standard deviation [SD]=2.8). There were 17 males, 1 female, and a variety of driving experience levels; a majority of participants with autism only had experience of a driving simulator bootcamp where they were taught skills of driving through use of the STISIM interactive driving simulator compared to the neurotypical participants where a majority held driver's license.

Table 1. Demographics by Group.

Group	N	Age M(SD)	Males/ Females	Driving Experience Level				
				Driver's License	Learner's Permit	Driver's Ed	Simulator/ Bootcamp	χ^2 , p-value
Autism	18	17.7 (2.8)	17/1	3	3	2	10	18.329, .001
Neuro- typical	15	19.1 (2.9)	9/6	13	2			

Instrumentation

The P-Drive (Patomella, 2014) was used as the primary outcome measure (dependent variable). P-Drive is a performance analysis assessment tool that evaluates driving ability on road and provided a “score” of the participants’ driving performance on the simulator. P-Drive was created to distinguish between safe and unsafe drivers in a standardized way across all locations and evaluators. It is a tool that can be used to evaluate driving both on road and in a simulator, and the occupational therapist scores only behaviors that are directly observed during driving (Patomella, 2014).

P-Drive provides scores in four main areas: maneuvers, orientate, follow regulations, and attending and responding (Patomella, 2014) as described in Appendix C. The P-Drive scores are based on a four-point scale for each driving skill. Specifically, a score of 4 indicates a competent performance that facilitates driving in a positive way, a 3 indicates a hesitant performance that causes insecurity, a 2 indicates an ineffective performance that causes risky situations, and a 1 indicates an incompetent performance. Patomella provides detailed descriptions for each score point (see Appendix D).

Previous assessment tools were limited in that they only collected data at the ordinal level, often summarizing data into one raw total score, which had the potential to be misleading and reduce assessment validity (Patomella, Tham, Johansson, & Kottorp, 2010). However, Rasch analysis results support P-Drive as a valid and reliable assessment tool for measuring on-road driving abilities (Patomella et al., 2010). Patomella and Bundy (2015) found that 96% of therapists’ scores fell within the acceptable range for goodness-of-fit for P-Drive, and Patomella et al. (2010) found that 95% of drivers demonstrated goodness-of-fit for P-Drive; the findings of both studies indicate acceptable person response validity. P-Drive furthermore uses an

interval/linear scale and shows high correlation between the interval scale and raw scores (Patomella et al., 2010; Patomella & Bundy, 2015). Patomella and Bundy (2015) found that there was a correlation of 0.88 between P-Drive raw scores and the interval measures, thus demonstrating the ability of P-Drive raw scores to be used to give an accurate depiction of an individual's ability to drive.

P-Drive can only be administered by individuals who have undergone training on the assessment tool to be qualified to use it (Patomella, 2014; Vaucher et al., 2015). A simple half-day training session is sufficient in equipping occupational therapists with the knowledge and tools necessary to reliably rate on-road driving performance (Vaucher et al., 2015). The PI was trained using the P-Drive and had experience with observing and scoring other drivers by watching the scenarios and comparing scores to an experienced P-Drive rater. Matching 90% of the time was required to be considered competent.

Equipment

The hardware of the driving equipment is the “Tran-Sit”, which consists of a driver's side door, passenger door, gas and brake pedals, steering wheel, a seat with seatbelt, and a gear for signaling right and left. There are some additional features such as reclining bench seat, bucket seats, height-adjustment, reaction-time tester, and tilt-steering column to personalize the simulator for best fit for each driver. The overall features of the Tran-Sit enhance driver positioning and activities on the simulator (Advanced Therapy Products, 2014).

The interactive driving simulator software is STISIM Drive for Occupational Therapists Scenario Descriptions guide (Systems Technology Inc., 2013). Specific scenarios were selected based off of previous experience and studies. A description of one scenario can be found in Appendix E (Road Test Version #1). Although three scenarios were named and used (e.g., Road

Test Version 1, Road Test Version 2, Road Test Version 3), the actual components of the scenarios are the same, but they occur in different orders. For example, Road Test Version 1 begins in an urban setting and Road Test Version 2 begins in a rural setting. While the critical events remained the same, the actual events of Road Test Version 1 were revised so that the participant did not “learn the scenario” over time and anticipate the specific critical event. For example, in one road test a man walks onto the street, and in another road test a child walks out farther down the road from a different direction.

The music/talk radio played through a Bluetooth speaker located at the front of the STISIM driving simulator to mimic the sound coming from the front speakers of a car.

Procedure

Prior to the start of recruitment, pilot trials were conducted with two individuals, and procedures were modified as needed to ensure that instructions and the environment were the same for all participants.

Prior to starting data collection, the PI spent some time getting acquainted and ensuring that the participant was comfortable with the researcher, the study, and the simulator. The PI oriented the participant with simulator parts (e.g. steering wheel, turn signal controls, pedals, seat adjustments, seat belt). The participant was assisted in adjusting the seat position as needed. Key instructions for the simulator were reviewed, and the participant was asked to do one or two accommodation drives until comfortable driving the simulator. If participants were not competent on their accommodation scenario, then they were thanked for their participation and dismissed from the remainder of the study.

The order of driving scenarios was the same for all participants so that any learning that occurred was the same. However, the order of music conditions was randomly assigned.

Participant were allotted an optional 5-minute break between drives to take as needed if they wanted to get up and walk around. Music volume was set and recorded prior to the start of each drive.

Once the driving scenarios were completed, the PI debriefed with the participant on their driving performance using a feedback form (see Appendix F). Discussion included areas of strength and areas for improvement so that the participant was able to learn from the experience. All participants were thanked for their participation with an iTunes or Amazon gift card; gift cards started at \$10 and increased to \$20 to increase recruitment at the end of the study. The one-time research session lasted 75-90 minutes.

Data Analysis

There were two types of outcome measures. The first outcome measure was the P-Drive raw score. This score was calculated by summing the scores for each P-Drive item (see Appendix C). Raw scores were also recorded for each subcategory of the P-Drive, including *Maneuvers*, *Orientate*, *Follow Regulations*, and *Attending and Responding*. The second of outcome measure was summary data from the driving simulator, including key statistics such as number of collisions, number of times over the speed limit, and number of times off the road (see Appendix G).

Descriptive statistics on demographics were used to describe the two groups in areas such as age, gender, and months of driving experience. Appropriate statistics (t test or Chi square) were used to compare the two groups on demographics. For P-Drive raw scores, repeated measures ANOVA was also used to determine if there were any differences between the three music conditions as well as any differences between groups. The output taken from the simulator consisted of ratio level data (e.g. brake reaction, percent of lane departure), which was

analyzed using repeated measures ANOVA to determine if there were any differences between the three music conditions as well as any differences between groups. Independent t-tests were also used to compare single measures between the ASD and neurotypical groups.

There was a significant effect of order and driving experience level, so these were controlled for throughout all analyses in the repeated measures ANOVA model as between-subject factors.

Chapter 4: Results

P-Drive as Outcome Measure

Table 2 displays the means and standard deviations of the total P-Drive scores as well as the four individual categories for all conditions for both groups overall. Table 3 displays the P-Drive scores separated by groups.

Table 2. Overall Repeated Measures ANOVA for P-Drive.

P-Drive Measures	No Music M(SD)	Classical M(SD)	Self-Selected M(SD)	F (df)	P-Value
Total	65.39 (9.92)	65.21 (8.65)	66.82 (9.23)	1.330 (10, 46)	.275
Maneuvers	17.64 (1.75)	17.76 (2.26)	17.70 (1.67)	0.149 (2, 46)	.862
Orientation	11.91 (2.04)	11.64 (1.85)	12.39 (1.87)	0.439 (2, 46)	.647
Regulations	9.06 (2.11)	9.42 (1.48)	9.21 (1.83)	4.390 (2, 46)	.018*
Attending and Responding	26.79 (5.45)	26.39 (4.99)	27.52 (5.59)	1.183 (2, 46)	.316
Note: * $p < .05$					

Table 3. Repeated Measures ANOVA for P-Drive by Group. Results of independent t-tests that compared the ASD and neurotypical groups between each condition are also included.

P-Drive Measures	Neurotypical					ASD					Independent T-test to Compare the Two Groups					
	N M(SD)	C M(SD)	S M(SD)	F (df)	p- value	N M(SD)	C M(SD)	S M(SD)	F (df)	p- value	N		C		S	
											t-value (df)	p- value	t-value (df)	p- value	t-value (df)	p- value
Total	68.40 (8.90)	67.47 (7.86)	67.07 (7.68)	1.153 (2, 16)	.340	62.89 (10.27)	63.33 (9.04)	66.61 (10.57)	5.132 (2, 18)	.017*	-1.651 (30.940)	.109	-1.405 (30.931)	.170	-0.143 (30.493)	.887
Maneuvers	18.47 (1.24)	18.20 (1.70)	18.00 (1.51)	1.816 (2, 16)	.195	16.94 (1.83)	17.39 (2.64)	17.44 (1.79)	0.816 (2, 18)	.458	-2.829 (29.927)	.008*	-1.066 (29.315)	.295	-0.967 (30.988)	.341
Orientation	12.40 (1.77)	12.27 (1.62)	12.47 (1.73)	0.616 (2, 16)	.553	11.50 (2.20)	11.11 (1.91)	12.33 (2.03)	1.275 (2, 18)	.304	-1.303 (30.966)	.202	-1.880 (30.976)	.070	-0.204 (30.978)	.840
Regulations	9.27 (1.94)	9.53 (1.19)	8.73 (1.62)	1.311 (2, 16)	.297	8.89 (2.27)	9.33 (1.72)	9.61 (1.94)	1.998 (2, 18)	.165	-0.515 (30.968)	.610	-0.394 (30.091)	.696	1.413 (30.998)	.168
Attending and Responding	28.27 (5.22)	27.47 (5.32)	27.87 (5.05)	0.277 (2, 16)	.762	25.56 (5.47)	25.50 (4.67)	27.22 (6.12)	4.318 (2, 18)	.029*	-1.454 (30.393)	.156	-1.118 (28.187)	.273	-0.331 (31.000)	.743
Note: N=No music, C=Classical music, S=Self-selected music. * p<.05.																

P-Drive: Total Scores

Repeated measures ANOVA showed no overall difference between the three music conditions ($F=1.330$, $p=.275$) for the total P-drive raw score. Additionally, there was no significant difference between the autism and neurotypical groups ($F=1.163$, $p=.292$) for the total P-Drive raw score (see Figure 3). Independent t-tests showed no significant differences between groups for the no music ($t=-1.651$, $p=.109$), classical ($t=-1.405$, $p=.170$), or self-selected ($t=-0.143$, $p=.887$) music conditions. Repeated measures ANOVA within the autism group alone showed a statistically significant difference between music conditions ($F=5.132$, $p=.017$), and a follow-up repeated measures ANOVA between pairs indicated that there was a significant difference between the no music and self-selected music conditions (no music: $M=62.89$, self-selected music: $M=66.61$, $p=.001$) (see Figure 4). The autism group did not show a significant difference between the classical and no music conditions ($F=2.468$, $p=.151$) or between the classical and self-selected music conditions ($F=1.212$, $p=.299$). Repeated measures ANOVA within the neurotypical group alone showed no significant difference between music conditions ($F=1.153$, $p=.340$).

Figure 3. P-Drive Total Scores by Group.

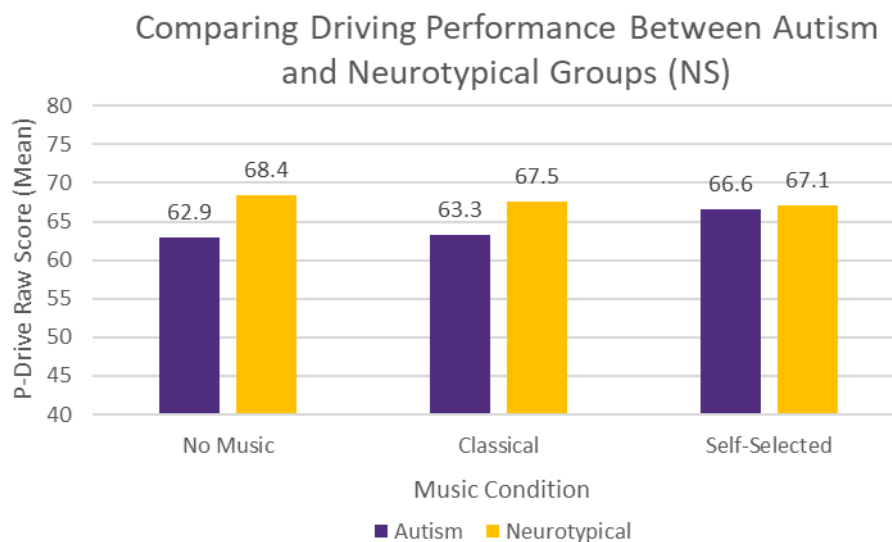
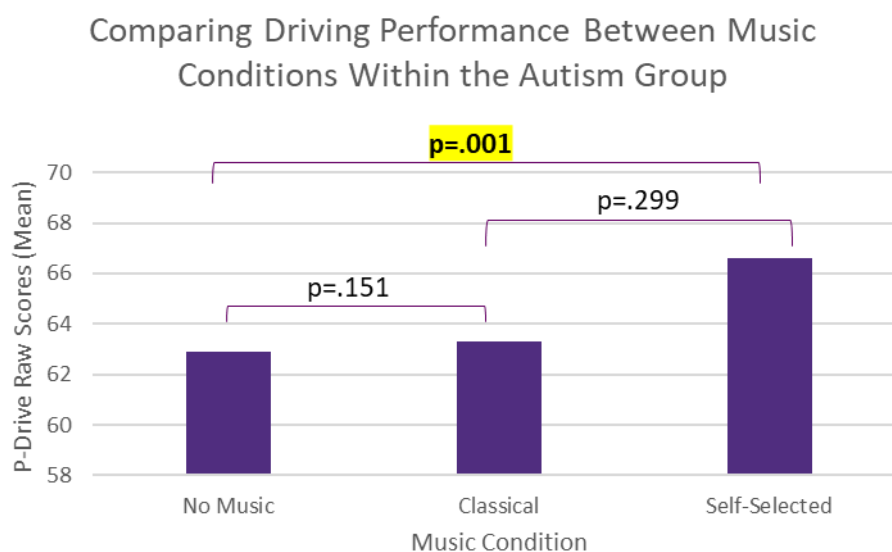


Figure 4. P-Drive Total Scores for the ASD Group.



P-Drive: Subcategories

Scoring of the category *Maneuvers* included abilities such as steering, using pedals, and using indicator. When totaled together, repeated measures ANOVA showed no difference overall between the three music conditions ($F=0.149$, $p=.862$) for the *Maneuvers* category. Additionally, there was no significant difference between the autism and neurotypical groups

($F=0.756$, $p=.394$) for this P-Drive category. No significant difference between music conditions was found within the autism group alone ($F=0.816$, $p=.458$) or within the neurotypical group alone ($F=1.816$, $p=.195$). However, during the no music condition, an independent t-test showed a significant difference between groups (ASD: $M=16.94$, neurotypical: $M=18.47$; $t=-2.829$, $p=.008$). There was no significant difference between groups under the classical ($t=-1.066$, $p=.295$) or self-selected conditions ($t=-0.967$, $p=.341$).

Scoring of the category of *Orientate* included abilities such as following instructions, positioning on road, and keep distance. When totaled together, repeated measures ANOVA showed no overall difference between the three music conditions ($F=0.439$, $p=.647$). Additionally, there was no significant difference between the autism and neurotypical groups ($F=2.480$, $p=.129$). No significant difference was found between the three music conditions within the autism group alone ($F=1.275$, $p=.304$) or within the neurotypical group alone ($F=0.616$, $p=.553$). Independent t-tests showed no difference between groups for the no music ($t=-1.303$, $p=.202$), classical ($t=-1.880$, $p=.070$), or self-selected ($t=-0.204$, $p=.840$) music conditions. However, the classical condition approached significance between the two groups.

Scoring of the category *Regulations* included abilities such as yielding, obeying stop, and following speed regulations. When totaled together, repeated measures ANOVA showed a significant difference in the P-Drive regulations category overall between the three music conditions ($F=4.390$, $p=.018$). Follow-up repeated measures ANOVA between pairs revealed a significant difference between the no music and classical music conditions (no music: $M=9.06$, classical: $M=9.42$; $F=4.974$, $p=.035$) as well as a significant difference between the no music and self-selected music conditions (no music: $M=9.06$, self-selected: $M=9.21$; $F=5.009$, $p=.035$). Repeated measures ANOVA showed no overall difference between the autism and

neurotypical groups ($F=0.756$, $p=.394$). Additionally, no significant difference was found within the autism group alone ($F=1.998$, $p=.165$) or within the neurotypical group alone ($F=1.311$, $p=.297$). Independent t-tests showed no difference between groups for the no music ($t=-0.515$, $p=.610$), classical ($t=-0.394$, $p=.696$), or self-selected ($t=1.413$, $p=.168$) music conditions.

Scoring of the category *Attending and Responding* included abilities such as reacting, problem solving, and attending to the left/right/center. When totaled together, repeated measures ANOVA showed no overall difference in P-Drive attending and responding scores between the three music conditions ($F=1.183$, $p=.316$). There was no significant difference between the autism and neurotypical groups ($F=1.611$, $p=.217$). Lastly, there was no significant difference within the neurotypical group alone ($F=0.277$, $p=.762$). However, there was a significant difference in scores between music conditions within the autism group alone ($F=4.318$, $p=.029$). A follow-up repeated measures ANOVA between pairs revealed that the group had the highest mean score under the self-selected condition when compared to no music (no music: $M=25.56$, self-selected: $M=27.22$; $F=17.261$, $p=.002$). Independent t-tests showed no difference between groups for the no music ($t=-1.454$, $p=.156$), classical ($t=-1.118$, $p=.273$), or self-selected ($t=-0.331$, $p=.743$) music conditions.

Driving Simulator Data

Table 4: Overall repeated measures ANOVA for driving simulator data.

Driving Simulator Measures	No Music M(SD)	Classical M(SD)	Self-Selected M(SD)	F (df)	P-Value
Number of collisions	0.85 (0.87)	0.85 (1.09)	0.67 (1.14)	1.279 (2, 46)	.288
Number of times over speed limit	1.97 (2.62)	1.55 (2.61)	1.88 (3.09)	3.219 (2, 46)	.049*
Percent of time over speed limit	1.99 (3.92)	1.34 (2.86)	1.60 (4.02)	4.700 (2, 46)	.014*
Number of times center line crossed	5.30 (1.69)	5.70 (1.55)	5.03 (1.53)	0.191 (2, 46)	.827
Number of times off road	6.03 (3.39)	6.27 (3.06)	6.15 (3.86)	7.826 (2, 46)	.001*
Percent of time out of lane	9.70 (3.47)	9.83 (3.51)	10.13 (3.64)	4.386 (2, 46)	.018*
Note: * $p < .05$					

Table 5: Repeated Measures ANOVA for Driving Simulator Data by Group. Results of independent t-tests that compared the ASD and neurotypical groups between each condition are also included.

Driving Simulator Measures	Neurotypical					ASD					Independent T-test to Compare the Two Groups					
	N M(SD)	C M(SD)	S M(SD)	F (df)	p- value	N M(SD)	C M(SD)	S M(SD)	F (df)	p- value	N		C		S	
											t-value (df)	p- value	t-value (df)	p- value	t-value (df)	p- value
Number of collisions	0.47 (0.74)	0.60 (0.83)	0.33 (0.62)	0.186 (2, 16)	.832	1.17 (0.86)	1.06 (1.26)	0.94 (1.39)	0.809 (2, 18)	.461	2.512 (30.937)	.017*	1.246 (29.559)	.223	1.675 (24.323)	.107
Number of times over speed limit	2.40 (2.32)	1.93 (2.60)	3.33 (3.87)	0.433 (2, 16)	.656	1.61 (2.85)	1.22 (2.65)	0.67 (1.50)	3.341 (2, 18)	.058	-0.876 (30.992)	.388	-0.775 (30.107)	.444	-2.519 (17.482)	.022*
Percent of time over speed limit	2.79 (4.89)	2.29 (3.91)	3.11 (5.64)	0.082 (2, 16)	.921	1.33 (2.86)	0.56 (1.18)	0.34 (0.69)	2.827 (2, 18)	.086	-1.017 (21.685)	.320	-1.649 (16.141)	.118	-1.888 (14.352)	.079
Number of times center line crossed	5.13 (1.36)	5.60 (1.50)	5.20 (1.26)	1.115 (2, 16)	.352	5.44 (1.95)	5.78 (1.63)	4.89 (1.75)	0.419 (2, 18)	.664	0.539 (30.146)	.594	0.326 (30.646)	.747	-0.592 (30.481)	.558
Number of times off road	4.33 (1.63)	5.00 (1.69)	4.13 (1.19)	0.436 (2, 16)	.654	7.44 (3.84)	7.33 (3.46)	7.83 (4.50)	3.242 (2, 28)	.063	3.117 (23.823)	.005*	2.465 (25.186)	.021*	3.350 (19.789)	.003*
Percent of time out of lane	10.05 (2.96)	9.73 (3.61)	9.69 (3.22)	0.146 (2, 16)	.865	9.41 (3.91)	9.92 (3.53)	10.50 (4.01)	1.974 (2, 18)	.168	-0.537 (30.754)	.595	0.152 (29.653)	.881	0.640 (30.972)	.527
Note: N=No music, C=Classical music, S=Self-selected music. * p<.05.																

Scoring of the measure *number of collisions* included the number of times the participant collided with another vehicle or a roadway object. Repeated measures ANOVA showed that there was no overall difference in number of collisions between the three music conditions ($F=1.279$, $p=.288$). Additionally, there was no significant difference between the autism and neurotypical groups ($F=0.139$, $p=.713$). Lastly, no significant difference was found between music conditions within the autism group alone ($F=0.809$, $p=.461$) or within the neurotypical group alone ($F=0.186$, $p=.832$). Under the no music condition, an independent t-test showed that there was a significant difference between groups for number of collisions (ASD: $M=1.17$, neurotypical: $M=0.47$; $t=2.512$, $p=.017$). However, there was no difference between groups under the classical ($t=1.246$, $p=.223$) and self-selected ($t=1.675$, $p=.107$) conditions.

The measure of *number of times over the speed limit* was used to demonstrate participants' adherence to regulatory signs such as speed limit signs. There was a significant difference overall for number of times over the speed limit between the three music conditions ($F=3.219$, $p=.049$). A follow-up repeated measures ANOVA between pairs revealed a significant difference between the no music and classical conditions (no music: $M=1.97$, classical: $M=1.55$; $F=12.964$, $p=.004$). Repeated measures ANOVA revealed no significant difference between the autism and neurotypical groups ($F=1.135$, $p=.256$). Additionally, there was no significant difference within the autism group alone ($F=3.341$, $p=.058$) or within the neurotypical group alone ($F=0.433$, $p=.656$). It should be noted that differences between conditions within the autism group did approach significance. Independent t-tests showed no significant difference between groups under the no music ($t=-0.876$, $p=.388$) or classical music ($t=-0.775$, $p=.444$) conditions. Under the self-selected condition, there was a significant difference between

groups for number of times going over the speed limit (ASD: $M=0.667$, neurotypical: $M=3.333$; $t=-2.519$, $p=.022$).

The measure of *percentage of time over the speed limit* was also used to demonstrate participants' adherence to regulatory signs such as speed limit signs. There was a significant difference overall on the percentage of time over the speed limit between music conditions ($F=4.700$, $p=.014$). A follow-up repeated measures ANOVA between pairs revealed a significant difference between the no music and classical conditions (no music: $M=1.99$, classical: $M=1.34$; $F=9.545$, $p=.005$) as well as a significant difference between the no music and self-selected conditions (no music: $M=1.99$, self-selected: $M=1.60$; $F=5.927$, $p=.023$). Repeated measures ANOVA showed no significant difference between the autism and neurotypical groups ($F=0.996$, $p=.329$). Additionally, no significant difference between music conditions was found within the autism group alone ($F=2.827$, $p=.086$) or within the neurotypical group alone ($F=0.082$, $p=.921$). Independent t-tests showed no difference between groups for the no music ($t=-1.017$, $p=.320$), classical ($t=-1.649$, $p=.118$), or self-selected ($t=-1.888$, $p=.079$) music conditions.

The measure of *number of times the center was crossed* was used as a reflection of lane position and lane-keeping abilities. Repeated measures ANOVA showed that there was no difference in number of times the center line was crossed between the three music conditions ($F=0.191$, $p=.827$). No significant difference was found between groups ($F=0.033$, $p=.857$). Lastly, no significant difference between music conditions was found within the autism group alone ($F=0.419$, $p=.664$) or within the neurotypical group alone ($F=1.115$, $p=.352$). Independent t-tests showed no difference between groups for the no music ($t=0.539$, $p=.594$), classical ($t=0.326$, $p=.747$), or self-selected ($t=-0.592$, $p=.558$) music conditions.

The measure of *number of times off road* was also used as a reflection of lane position and lane-keeping abilities. There was a significant difference overall between music conditions ($F=7.826$, $p=.001$). Follow-up repeated measures ANOVA between pairs revealed a significant difference between the no music and self-selected conditions (no music: $M=6.03$, self-selected: $M=6.15$; $F=19.461$, $p=.001$) as well as between the classical and self-selected conditions (classical: $M=6.27$, self-selected: $M=6.15$; $F=5.265$, $p=.031$). Repeated measures ANOVA showed that there was no significant difference in number of times going off the road between the autism and neurotypical groups ($F=0.728$, $p=.402$). Lastly, no significant difference between music conditions was found within the autism group alone ($F=3.242$, $p=.063$) or within the neurotypical group alone ($F=0.436$, $p=.654$). A series of independent t-tests revealed that under the no music condition, there was a significant difference between groups for number of times off road (ASD: $M=7.44$, neurotypical: $M=4.33$; $t=3.117$, $p=.005$). Under the classical condition, there was a significant difference between groups for number of times off road (ASD: $M=7.33$, neurotypical: $M=5.00$; $t=2.465$, $p=.021$). Under the self-selected condition, there was a significant difference between groups for number of times off road (ASD: $M=7.83$, neurotypical: $M=4.13$; $t=3.350$, $p=.003$).

The measure *percentage of time out of lane* was included as another reflection of lane position and lane-keeping abilities. There was a significant difference overall between the three music conditions ($F=4.386$, $p=.018$). A follow-up repeated measures ANOVA between pairs revealed a significant difference between the classical and self-selected conditions (classical: $M=9.83$, self-selected: $M=10.13$; $F=5.603$, $p=.027$) as well as between the no music and self-selected conditions (no music: $M=9.70$, self-selected: $M=10.13$; $F=14.955$, $p=.001$). Repeated measures ANOVA revealed that there was no significant difference in percentage of time out of

the lane between the autism and neurotypical groups ($F=0.174$, $p=.681$). Lastly, no significant difference between music conditions was found within the autism group alone ($F=1.974$, $p=.168$) or within the neurotypical group alone ($F=0.146$, $p=.865$). Independent t-tests showed no difference between groups for the no music ($t=-0.537$, $p=.595$), classical ($t=0.152$, $p=.881$), or self-selected ($t=0.640$, $p=.527$) music conditions.

Volume Correlation

There was not a significant correlation between music volume and P-Drive total scores under the self-selected music condition overall ($r=-.033$, $p=.856$). Additionally, no significant correlation between music volume and driving performance for the P-drive total score was found within the autism group alone ($r=.159$, $p=.529$) or within the neurotypical group alone ($r=-0.402$, $p=.138$).

Chapter 5: Discussion

The purpose of this pilot study was to investigate the effects of background music on the driving performance of ASD individuals as compared with neurotypical individuals. Results suggest that background music/radio does not affect driving performance of a teen/young adult when using an interactive driving simulator. The implication would be that playing background music may not hinder driving performance, providing contesting evidence against the common assumption that music is a distraction while driving. Fast tempo music is a known cause of driving errors (van der Zwaag et al., 2013), but even still, the self-selected music, which inherently included some fast tempo song choices, did not differ significantly from the other conditions. It may be that unfamiliar fast tempo music is distracting, but when it is self-selected familiar fast tempo music, it is not a distraction and therefore does not make a difference in driving. While there were select differences between the three music conditions, including scoring in P-Drive *Regulations*, number of times over the speed limit, percent of time over the speed limit, number of times off the road, and percent of time out of the lane, there was no clear pattern showing that one music condition yielded better performance.

Participants in the present study performed best overall with classical music in the outcome measures of P-Drive *Regulations* (includes yielding, stopping, and following speed regulations), number of times over the speed limit, and percent of time over the speed limit, which suggests overall that classical music is linked with best performance regarding speed regulation. This finding may be explained by evidence demonstrating that classical music can improve concentration and activity engagement (Anders, 2011; Preis et al., 2016), which may allow for more accurate pedal control. Participants in the present study performed best overall with no music in the outcome measures of number of times off the road and percent of time out

of lane, which suggests overall that no music is linked with best performance regarding lane keeping and positioning on road. This finding may be explained by evidence in which participants demonstrated better task attention with no music when compared to classical and hip-hop music (Chou, 2010), which may translate to successful steering wheel control allowing for better lane position. Historically, there have been discrepancies between a live in-person rater and driving simulator summary data, likely due to the simulator being limited in sensitivity to driving performance (Classen et al., 2013). Accordingly, the better outcome measure in the present study is the P-drive, as it was scored live and in-person by a trained rater. P-drive findings should therefore be prioritized as more accurate over findings from the simulator summary statistics.

No overall difference was found in driving performance between the ASD and neurotypical groups looking at the P-drive total outcome measure. Previous studies indicated that participants with ASD perform worse when compared to healthy controls regarding reaction time, working memory, lane maintenance, speed regulation, visual attention, and identifying hazards (Sheppard et al., 2010; Reimer et al., 2013; Cox et al. 2016; Classen et al., 2013). However, findings of the present study refute these findings, thus showing that individuals with ASD can and do drive just as well as their neurotypical counterparts when compared on an interactive driving simulator. Many individuals with ASD also experience sensory processing difficulties (Rodger & Ziviani, 2012), which can make it difficult to respond to the complex and ever-changing driving environment. However, the lack of difference in driving performance between the two groups suggested that this was not an issue for drivers with high-functioning autism.

There were select differences between the ASD and neurotypical groups under different music conditions in a few outcome measures, primarily those taken from driving simulator statistics. Under the no music condition, groups differed significantly in the number of collisions, number of times off road, and P-Drive *Maneuvers*. Under the classical music condition, groups differed significantly in number of times off road. Under the self-selected music condition, groups differed significantly in number of times over speed limit and number of times off road. The neurotypical group performed best in all of these outcome measures except for number of times over the speed limit in the self-selected music condition. These findings provide some support to previous findings that healthy controls perform better than participants with ASD (Sheppard et al., 2010; Reimer et al., 2013; Cox et al. 2016; Classen et al., 2013), however a majority of findings showed no difference between the two groups. A possible explanation for the neurotypical group performing worse in speeding errors while listening to self-selected music is that the familiarity and likeability of self-selected music may have caused the neurotypical group to become absorbed in the music and make more speeding errors, while the familiarity and likeability of the self-selected music caused the autism group to relax, reduce anxiety, and make fewer speeding errors.

Interestingly, upon further examination of the ASD group, it was found that there was a significant difference between music conditions. For individuals with ASD, self-selected music enhanced their performance; that is, they performed better with the music they chose to listen to when driving on the simulator. This result offers promise in the use of self-selected music to modulate the environment, allowing for better processing and performance in the complex daily activity of driving. If specific auditory sensory strategies (e.g. self-selected music) can be used to modulate the environment for individuals with ASD, reduce tension-anxiety, and improve

attention to create optimal occupational performance (Cassidy & MacDonald, 2009), then the same strategy can be applied to driving. Additionally, the findings can provide guidance for parents of teens with ASD regarding optimal driving environment as teens begin driving. Therefore, under the optimal driving conditions, individuals with ASD may be able to consistently demonstrate driving performance equal to neurotypical individuals.

The lack of significant correlation between volume and driving performance refutes the common assumption that higher volumes are linked with poorer driving performance. In fact, this finding supports a previous finding that driving performance with loud volume music does not differ from driving performance with moderate volume music (Unal et al., 2013). However, the volume produced by the speaker system used in the present likely does not go as loud as that of a car, so there could be implications for higher music volumes that were not accessible through the speaker in the present study.

Of note, there was a significant interaction between the order of music conditions. No clear pattern was revealed among the six different music orders, but certain orders stood out from the rest. Overall, participants averaged much higher scores in driving performance when their music order was 1) no music, 2) classical, and 3) self-selected. With this order, there was also a positive growth trend, meaning that driving performance improved with each drive. For the ASD group, participants again average much higher scores in driving performance when the music order was 1) no music, 2) classical, and 3) self-selected. There was a positive growth trend here as well where driving performance improved with each drive and each type of music. Also of note for the ASD group, participants demonstrated the largest decline in driving performance with the music order of 1) self-selected, 2) classical, and 3) no music. Interestingly, the music order of the largest decline in performance was the opposite of the music order for

greatest improvement. This provides stronger support to the finding that the ASD group performs best with self-selected music. For the neurotypical group, participants demonstrated the greatest improvement with the music order 1) classical, 2) self-selected, and 3) no music, however average scores did not greatly differ from the other music orders for this group.

Research shows that driving simulator performance is highly correlated with on-road driving performance (Lee, Cameron, & Lee, 2003), which offers promise for the findings of the present study to translate well to on-road driving. While the ASD group was more inexperienced than the neurotypical group regarding driving experience, there still was no significant difference in performance overall across music conditions on the driving simulator. It is therefore expected that there would be no significant difference between the two populations on the road as well. In fact, this was a surprising finding, as most of the ASD participants had limited to no on-road experience, and it would have been expected that they make more driving errors. These findings suggest that young drivers with high-functioning ASD have equal potential to be successful drivers compared to their neurotypical counterparts.

Chapter 6: Implications for Occupational Therapy Practice

This study informs occupational therapists and driving instructors of the potential for self-selected music to improve driving performance for individuals with ASD, but also of the freedom to use classical and self-selected music without there being a significant effect on driving performance for neurotypical individuals. It should still be noted that drivers in the present study demonstrated better speed regulation with classical music and better lane position without music. Driving specialists should use this information to select appropriate music specific to what driving skills they are trying to develop with their clients, thereby taking an individualized and client-centered approach to driving rehabilitation.

Chapter 7: Limitations

One limitation of the study was the learning curve of the driving simulator. Critical events that occur on the driving simulator are similar to each other, and it can become easy to predict where and when critical events will occur. To minimize the learning curve, each drive had differences in critical event location and timing so that participants could not predict events.

Another limitation of the study was use of the driving simulator itself. While it would be ideal to observe participants on the road in real-life situations to get the most accurate depiction of their driving skills, it is not always feasible or safe to do so. A majority of ASD participants only had the experience of a driving simulator bootcamp or a 10-session intervention teaching them the basic tenets of driving. These participants had solely driven on the driving simulator, and they had no real-life on-road driving experience. It could be postulated that those with ASD are just better simulator drivers, as they had more experience on the driving simulator as compared to the neurotypical drivers. The high relationship between simulator driving and on-road driving helps to minimize the effects of this limitation.

A third limitation of the study was that the PI was the only person scoring participants on the P-Drive, so no interrater reliability could be determined. Results of the study would be stronger with 2-3 raters demonstrating interrater reliability.

Chapter 8: Conclusion

The literature overall indicates that individuals with ASD often experience difficulties in sensory processing and consequently perform worse than healthy controls in various driving situations. With the varying complex and dynamic driving environment and consideration of the sensory input that occurs while driving, it was still thought that individuals with ASD would perform worse than neurotypical individuals. However, findings indicated overall that there was no difference between the ASD and neurotypical groups in their driving performance, suggesting that there is equal potential for young adults with ASD to be successful drivers.

Existing studies examining how music affects attention and driving provided mixed results regarding if no music, classical music, or self-selected music improves performance in areas such as attention, engagement, and driving. Overall, background music/radio does not affect driving performance of a teen/young adult when using an interactive driving simulator. This means that young drivers can listen to music without any negative impact on their driving abilities. There was also no difference in driving performance between neurotypical drivers and drivers with ASD, which suggests that drivers with ASD can be successful drivers. However, drivers with ASD drive better with self-selected music. Thus, for drivers with ASD, self-selected background music may offer the most promise in modulating the environment to allow for better processing and performance in the complex daily activity of driving

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Appendix A

Participant Questionnaire

1. Age: _____
2. Gender (Circle): Male Female Other: _____
3. **Optional:** Have you been diagnosed by a doctor with a form of Autism Spectrum Disorder (i.e. Autism, Autistic Disorder, Asperger's Syndrome)? Yes No
4. Have you completed a Driver's Education course? Yes No
 - a. If "Yes", when did you complete your Driver's Education course?

 - b. If "No", are you currently enrolled in a Driver's Education course? Yes No
5. Do you possess a valid Driver's License? Yes No
 - a. If "Yes", please list the date your Driver's License was issued:

 - b. If "No", do you possess a valid Driving Permit? Yes No
 - i. If "Yes", please list the date your Driving Permit was issued:

6. How many years/months of driving experience do you have? _____ years _____ months
7. Have you ever driven on a driving simulator? Yes No
 - a. If "Yes", describe: _____
8. Do you wear glasses or contact lenses to help you see? Yes No
9. Do you have an uncorrected vision impairment? Yes No
10. Have you ever experienced motion sickness (vomiting, dizziness, nausea from the movement of a car)? Yes No

Appendix B

Participant Consent Form & IRB Approval

East Carolina University



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 Driving Performance in Individuals with Autism Spectrum Disorder Compared to Neurotypical Individuals

Principal Investigator: Brittany Goehmann

Institution, Department or Division: Department of Occupational Therapy

Address: Allied Health Science Building

Telephone #: (248)275-8853

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 determine the effect of background music on driving performance in individuals with Autism Spectrum Disorder (ASD) as compared to neurotypical individuals. Music can be a useful therapeutic tool, so we are examining if music improves driving performance. You are being invited to take part in this research because you meet the necessary criteria, either having high functioning ASD or a neurotypical young adult. The decision to take part in this research is yours to make. By doing this research, we hope to learn if the presence of different types of background music affect driving performance in individuals with ASD as compared to neurotypical individuals.

If you volunteer to take part in this research, you will be one of about 40 people to do so.

Are there reasons I should not take part in this research?

You should not volunteer for this study if you do not have any driving experience either on road or with a driving simulator.

Where is the research going to take place and how long will it last?

The research will be conducted at East Carolina University in the Allied Health Sciences Building. You will need to come to 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:

1. Prior to coming to your session, you will be asked to prepare a playlist with 6-8 songs that are at least 3 minutes in length. You should bring this playlist with you to your meeting. The playlist can be in the form of a CD, a written list, iPod, or other listening device.

Research Meeting:

2. I will introduce you to the driving simulator equipment and give you time to get comfortable learning the equipment.
3. If needed, we will do a test drive to help you get comfortable and become familiar with the feeling of driving in the driving simulator if you are unfamiliar.
4. You will be asked to complete three drives on the simulator, each lasting about 10-12 minutes. With each driver, there will be different background music played.
5. You will be given a 5-10 minute break in between each drive to rest or get up and move around.
6. All of your drives will be recorded so that the researchers can re-watch them if there are any questions about your driving performance. You will not be included in the recording; it will only record the computer monitors on the simulator.
7. After you complete your drives, I will provide you with a summary score sheet. We will debrief on your driving session to talk about strengths and weaknesses of your driving performance.

What might I experience if I take part in the research?

While most young adults do not get motion sickness, it is possible you may experience simulator sickness. We will watch you carefully, ask questions, and stop if you begin to feel uncomfortable. There are no other risks associated with 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. However, you may find out how distracted you are with specific types of music playing.

Will I be paid for taking part in this research?

We will not be able to pay you for the time you volunteer while being in this study. However, we will offer a \$20 gift card from Amazon.

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.
- 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 secure by using a participant identification number rather than your name. Participant files will be stored in a secure cabinet in a secure room. Data and any identifying information will be kept for no more than three years. However, data on the simulator may be kept longer, but any identification will not be linked to you personally.

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 Brittany Goehmann at (248)-275-8853 (Weekdays, between 9am and 5pm).

If you have questions about your rights as someone taking part in research, you may call the Office of Research Integrity & Compliance (ORIC) 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 of the ORIC, at 252-744-1971.

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
---	------------------	-------------

Principal Investigator (PRINT)	Signature	Date
(If other than person obtaining informed consent)		



EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
 4N-70 Brody Medical Sciences Building - Mail Stop 682
 600 Moye Boulevard - Greenville, NC 27834
 Office 252-744-2914 - Fax 252-744-2284 - www.ecu.edu/ORIC/irb

Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
 To: [Brittany Goehmann](#)
 CC: [Anne Dickerson](#)
 Date: 7/17/2017
 Re: [UMCIRB 17-001211](#)
 Effects of background music on driving performance

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 7/17/2017 to 7/16/2018. The research study is eligible for review under expedited category #6, 7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

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

The approval includes the following items:

Name	Description
Email recruiting for participants.docx	Recruitment Documents/Scripts
Informed Consent Goehmann.doc	Consent Forms
Minor Assent Form Goehmann.doc	Consent Forms
Parental Permission Form Goehmann.docx	Consent Forms
Participant Debriefing Form.docx	Additional Items
Participant Flyer.pub	Recruitment Documents/Scripts
Participant Screening Questionnaire	Surveys and Questionnaires
The Effects of Background Music/Talk Radio on Driving Performance in Individuals with Autism Spectrum Disorder Compared to Neurotypical Individuals	Study Protocol or Grant Application

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

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

Appendix C

P-Drive Score Sheet



-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 D

P-Drive Scoring Manual



-Drive

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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 in an 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 in an 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 hesitantly 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 position 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 to attend 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 E

Road Test Version 1 Description and Outcome Measures

SCENARIO	DESCRIPTION	MEASURES	
Road Test Version 1	Length/Time: 4.2 miles ~10.5 minutes	Total Off Road Crashes (Ratio) Total Collisions with Vehicles & Roadway Objects (Ratio)	Hidden Stop Performance: Did the Driver Stop in Time (Nominal) Distance from Stop Sign when Brakes Applied (Ratio)
	Scenario runs through metro, rural farmland, school zone, and residential condos scenes.	Total Traffic Light Tickets (Ratio) Total Times Over the Posted Speed Limit (Ratio) Percentage of Time Over the Posted Speed Limit (Ratio)	Vehicle Pulling into Traffic: Collision with Vehicles (Nominal) Total Pedal Reaction Time (Ratio) Gas Pedal Reaction Time (Ratio) Minimum Time to Collision with Vehicles in the Driver's Lane (Ratio)
	The basic scenario scenes are identical except for the presentation order. The presentation of various hazards does change for each version of the Road Test.	Total Times Center Line was Crossed* (Ratio) Total Times the Driver went Off the Road** (Ratio) Percentage of Time Out of Lanes (Ratio)	Vehicle Control Performance Average Speed (Ratio) Speed Deviation (Ratio) Average Lane Position (Ratio) Lane Position Deviation (Ratio) Maximum Speed (Ratio) Minimum Speed (Ratio)
	Road Test Versions can be used for pre/post rehabilitation assessments.	Pedestrian Collision Avoidance: Collision with Pedestrians (Nominal) Total Pedal Reaction Time (Ratio) Gas Pedal Reaction Time (Ratio) Minimum Time to Collision with Pedestrians (Ratio) Minimum Distance to Pedestrian (Ratio) Did the Driver Exceed the Posted Speed Limit (Nominal) Maximum Speed in School Zone (Ratio)	Head On Collision Avoidance: Collisions with Vehicles (Nominal) Off Road Crash (Nominal) Total Pedal Reaction Time (Ratio) Gas Pedal Reaction Time (Ratio) Was Excessive Steering Used (Nominal) Minimum Time to Head on Collision (Ratio) Minimum Distance to Head on Collision (Ratio)
	*-Has to be left of center once to pass bus and bicycle	Amber Dilemma Performance: Did the Driver Stop (Nominal) Total Pedal Reaction Time (Ratio) Gas Pedal Reaction Time (Ratio)	Sudden Lead Vehicle Braking Collision with Vehicles (Nominal) Total Pedal Reaction Time (Ratio) Gas Pedal Reaction Time (Ratio) Minimum Time to Collision with Vehicle in the Driver's Lane (Ratio) Minimum Distance to Vehicles in the Driver's Lane (Ratio)
	**_-Has to be off road once due to Head on Collision	Turn Performance: Did the Driver Turn in the Correct Direction (Nominal) Did the Driver Crash While Turning (Nominal) Was the Turn Signal Used Correctly (Nominal) Did the Driver Pass in Front of Pedestrian (Nominal)	Turn Performance Did the Driver Turn in the Correct Direction (Nominal) Collision with Vehicles (Nominal) Collision with Pedestrians (Nominal) Was the Turn Signal Used Correctly (Nominal) Did the Driver Pass in Front of Pedestrians (Nominal)

Appendix F

Participant Debriefing Form

Participant Debrief Form				
Driving Skill	Caused risky situations	Needs Improvement	Hesitant Performance	Excellent Performance 😊
Driving Speed:				
Turning:				
Lane position:				
Changing lanes:				
Using blinkers/signals:				
Awareness of other road users:				
Awareness of pedestrians:				
Obeying Stop Signs:				
Following instructions:				
Using mirrors:				

Comments:

Appendix G

Sample Output of Simulator Data

Summary of Simulation Results	Value
<i>Driver Mistakes</i>	
Total number of off road crashes =	0
Total number of collisions with vehicles and other roadway objects =	0
Total number of collisions with pedestrians =	0
Total number of traffic light tickets =	0
Total number of stop sign tickets =	0
Total number of times over the posted speed limit =	0
Percentage of time over the posted speed limit =	0.00
Total number of times the center line was crossed =	3
Total number of times the driver went off the road =	4
Percentage of time out of lanes =	12.72