TEENS WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER:

FACTORS ASSOCIATED WITH DRIVING ERRORS

A Thesis submitted to the faculty at Stanbridge University in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy.

by

Kathlyn Decena, Angie Higa, Cristina Jones, and Ellery Lockwood

Thesis advisor: Sheryl Ryan, PhD, OTR/L

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Certification of Approval

I certify that I have read Teens with Attention-Deficit/Hyperactivity Disorder: Factors Associated with Driving Errors by Kathlyn Decena, Angie Higa, Cristina Jones, and Ellery Lockwood, and in my opinion, this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy at Stanbridge University.

Sheryl Ryan, PhD, OTR/L
Assistant Professor of Occupational Therapy

ACCEPTED

Vikas Sharma, OTD, OTR/L
Program Director, Master of Science in Occupational Therapy

Abstract

While teenage drivers are at a higher risk for driving accidents, that risk is four-fold in drivers with attention-deficit/hyperactivity disorder (ADHD). Driving entails the coordination of complex executive functions (EF) and intact sensory processing (SP), both of which are impacted in individuals with ADHD. This descriptive case study was focused on exploring relationships between executive functions, sensory processing patterns, and driving errors committed on a virtual driving simulator by four teenage drivers diagnosed with ADHD. Measures included the Comprehensive Executive Function Inventory (CEFI), Adolescent/Adult Sensory Profile (AASP) self-report, standardized intake form, and driving errors committed on the STISIM Drive driving simulator. The methodology incorporated a correlational factor analysis to determine the nature and strength of relationships between subcomponents of each of the measures for the participants. Results corroborated evidence from an intensive literature review that suggested an overall connection between executive functioning and driving errors. No correlations were found between driving errors and sensory processing patterns. These results support the existing evidence stating that deficits in executive functions have a direct impact on driving performance, particularly for novice teen drivers. Findings from this study can be used to further guide occupational therapy practitioners in evidence-based practice, such as using a driving simulator with varied obstacles to promote repeated practice in novel driving situations in an attempt to produce adaptive responses on the road. Further research is warranted to determine ways to further improve testing, training, positive driving outcomes for teen drivers and those with ADHD.

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Teens with ADHD: Factors Associated with Driving Errors

Learning to drive for teens can be difficult as it requires many novel skills, but certain factors can make it riskier or more challenging, particularly for teens with attention-deficit/hyperactivity disorder (ADHD). Currently, motor vehicle collisions are the leading cause of death and injury in teenagers worldwide (Centers for Disease Control [CDC], 2015; World Health Organization [WHO], 2015). High rates of motor vehicle collisions have effects on health, finances, employment, relationships, and well-being.

Statement of the Problem

Safe driving for teens with ADHD is a current and relevant topic for occupational therapists that requires further knowledge to inform evidence-based practice.

Teens with ADHD are at a Greater Risk While Driving

There are high rates of motor vehicle accidents associated with teen drivers overall. Particularly, teens with ADHD that experience symptoms impacting the skills needed for safe driving are at a higher risk of being involved in accidents (Classen, Monahan, & Wang, 2013; Narad et al., 2013; Shechtman, Classen, Awadzi, & Mann, 2009). Teen drivers with ADHD have 4 times the rate of motor vehicle accidents than their neurotypical peers (Jerome, Segal, & Habinski, 2006). Research has shown executive functioning to be closely associated with driving ability (Mäntylä, Karlsson, & Marklund, 2009). Executive functioning involves higher-level processing skills that are often impaired in individuals that experience ADHD symptoms; these skills are especially important for sustaining attention while driving, avoiding hazards and obstacles, planning routes, and using safe judgment in varied driving conditions (Barkley, Murphy, Dupaul, & Bush, 2002; Classen & Monahan, 2017; Fischer, Barkley, Smallish, & Fletcher, 2007; Lee & Yang, 2019; Walshe, McIntosh, Romer, & Winston, 2017).

The existing literature has documented that teens with ADHD have more driving accidents and get more tickets than neurotypical peers (Curry et al., 2017). It is also known that driving errors are associated with difficulties in executive functions (EF) for people with ADHD and autism spectrum disorder (ASD) (Curry et al., 2017; Classen, Monahan, & Hernandez, 2013). Some studies have examined types of driving errors made on a simulator (Classen & Monahan, 2017; Classen, Monahan, & Brown, 2014; Mäntylä, Karlsson, & Marklund, 2009; Martin & Elefteriadou, 2010; Ratzon, Lunievsky, Ashkenasi, Laks, & Cohen, 2017; Shechtman et al., 2009), while other studies have addressed specific areas of EF related to driving (Pope, Ross, & Stavrinos, 2016; Walshe et al., 2017). We were unable to locate any studies that examined the relationship between sensory processing (SP) and driving errors among teens with ADHD. Many of the existing studies have used driving simulators, which have been found to be an effective tool for assessing and training driving-related skills that produce reliable results (Classen & Monahan, 2017; Shechtman et al., 2009). Further research is needed to determine how SP and specific aspects of EF may impact driving performance for teens with ADHD.

The purpose of our research study was to examine and describe the relationship between EF and SP with driving errors committed on a driving simulator for teens with ADHD. We hypothesized that impairments in EF and SP would correlate with errors made on a driving simulator. We anticipated there would be correlations between specific EF and SP skills in relation to driving errors, such as sustained attention skills and lane maintenance on long rural roads. Ultimately, we hoped to discover which specific aspects of SP and EF were most related to driving simulator errors in order to inform future occupational therapy (OT) intervention efforts among teen drivers with ADHD.

Significance to Occupational Therapy

The occupation of driving is not only an essential instrumental activity of daily living for most adults, but it also serves as an occupation enabler (American Occupational Therapy Association [AOTA], 2017; Scaffa & Reitz, 2014). As an occupation enabler, driving allows people to independently access their meaningful work, social, and leisure activities (Scaffa & Reitz, 2014). For teens, driving is an important milestone that represents their development of independence and responsibility. For most people, regardless of age, driving is an activity that keeps them connected to the people and events that bring them meaning (AOTA, n.d.). It is crucial that OT practitioners have the evidence we need to address driving risks among teens with ADHD to guide our client-centered assessments and interventions. Occupational therapy practitioners can also use the results obtained from this study to assess, train, and create treatment strategies for teen drivers with ADHD that can ultimately guide OT interventions.

More available knowledge regarding the risks for teen drivers with ADHD could potentially lead to interventions that provide increased safe access to occupations and environments that result from independent community mobility. This study is consistent with the aims of the AOTA’s Vision 2025 which focuses on continuing the profession’s focus on utilizing evidence-based, client-centered, and cost-effective strategies to enhance client outcomes that will increase participation in meaningful occupations and roles (AOTA, 2016). The pillars of Vision 2025 include a focus on population health, which means that OT practitioners have a goal of maximizing health, well-being, and quality of life for all people, populations, and communities (AOTA, 2016). This study ultimately contributes to the pillars of well-being and quality of life by increasing the knowledge base about driving abilities of teens with ADHD to enable them within their chosen occupations through community mobility.

Literature Review

As previously stated, motor vehicle collisions are the leading cause of death and injury in teens worldwide (CDC, 2015; WHO, 2015). In North America, one-third of all teen deaths and over 259,000 injuries are from motor vehicle collisions (CDC, 2015; Transport Canada, 2013). The risk of being involved in a crash is four times higher for teens with ADHD due to deficits in visual, sensory, cognitive, and motor functioning (Classen, Monahan, & Hernandez, 2013; Classen, Monahan, & Brown, 2014; Jerome et al., 2006). Teens with ADHD are also four times as likely to be at fault in a motor vehicle collision (McKnight & McKnight, 2003). Researchers have shown that a lack of driving experience, impaired decision-making abilities, and increased risk-taking behaviors are contributing factors, all of which are associated with ADHD (Ascone, Lindsey, & Varghese, 2009).

Attention-Deficit/Hyperactivity Disorder

ADHD is one of the most common neurodevelopmental disorders that continue into adolescence and adulthood (National Institute of Mental Health [NIMH], 2011). The American Psychiatric Association (APA) indicates that ADHD prevalence is widespread across most cultures, with rates as high as 5% in children and about 2.5% of adults (2013). ADHD is diagnosed as one of three types; inattentive, hyperactive/impulsive, or combined with impairments of cognitive, emotional, and social functioning (APA, 2013). Individuals with ADHD may display fidgety behaviors, a propensity to speak out, interrupt others, and be unable to adapt to changing situations (APA, 2013). The brain matures at a slower rate in children with ADHD by an average of 3 years, particularly in the frontal cortex that controls EF, including attention, planning, and decision making (NIMH, 2011). Slower maturation rate impairs a child's ability to inhibit unwanted thoughts or actions, focus their attention, effectively remember important information, and proficiently sustain goal-directed behaviors in pursuit of rewards (NIMH, 2011). One in six teens with ADHD have severe SP symptoms that negatively impact activities of daily living such as dressing, bathing, and eating (AOTA, 2017; Ben-Sasson, Carter, & Briggs-Gowen, 2009). Pfeifer et al. (2014) found that symptoms of SP dysfunction can affect individuals with ADHD in areas of social participation and motor coordination. Clinical presentations of ADHD in childhood and adolescence are most notably seen in reduced performance in school-related tasks, which are highly associative with impairments in EF (APA, 2013). ADHD impacts all areas of life, including aspects of SP and EF that ultimately affects family functioning, social relationships, and educational success. These effects are due to a varied presentation of symptoms caused by inattention, hyperactivity, and impulsivity (APA, 2013; Barkley, 2002). Other disorders that co-occur with ADHD are anxiety, depression, oppositional defiant disorder, conduct disorder, and higher use of alcohol and drugs (Murphy & Barkley, 1996a, Murphy & Barkley, 1996b). Researchers have found that teens with ADHD have less driving knowledge, less competent handling of a simulated vehicle, and less safe driving habits (Barkley et al., 2002; Classen & Monahan, 2017; Narad et al., 2013).

Executive Functioning

EF is a necessary mental process required for cognitive tasks, but in individuals with ADHD EF is impaired, especially at a young age (APA, 2013). The impairment in EF affects how developing adolescents perform in a variety of tasks related to academics, work activities, driving, and even social interactions. Various tasks require the ability to volitionally control planning, sequencing, initiation, and monitoring skills, which leads to goal-directed behavior within multi-step tasks (Royall et al., 2002). Despite the importance that EF holds within our neurobehavioral systems, there are still varying definitions and theories related to the inner workings of these processes and the role they play in neurodevelopmental disorders. Adele Diamond is a leading researcher in the quest to understanding EF, particularly in individuals diagnosed with ADHD. The three general processes that Diamond (2013) defines as comprising EF include inhibition (used to inhibit control over behavior and cognition as well as for selective attention properties), working memory (associated with short term memory), and cognitive flexibility (allowing for shifts and adjustments in each environment or situation). While the development of EF varies between individuals and continues to improve into young adulthood, there can be detrimental consequences associated with immature EF and everyday tasks (APA, 2013). As King, Colla, Brass, Heuser, and Von Cramon (2007) found in their study, ADHD manifestations continue to affect adults, as illustrated by their abnormal, cognitive interference processing patterns when presented with task-irrelevant stimulus on two distinct tasks, which resulted in less efficient response patterns. This sustained symptomology throughout the lifespan in individuals with ADHD can continually affect safety while driving. Therefore, it is important to understand the relationship between EF and driving to inform practitioners on possible interventions regarding ADHD symptomatology and driving.

Executive functioning and driving. Driving requires the use of various EFs, particularly at the novice level before performance becomes less effortful and more automatic. Inefficient or immature EFs of young adults increases the risk of driving errors and accidents because the executive control of higher-order systems required of novice drivers may not be fully developed at younger ages (Mäntylä et al., 2009; Pope et al., 2016). Pope et al. (2016) have stated that teens may have difficulties with prospective thinking, decision making, and updating information before becoming experienced drivers, difficulties that lead to more negative driving outcomes. This was corroborated by Ross, Jongen, Brijs, Ruiter, Brijs, and Wets (2015) who found that decreased response inhibition and verbal working memory performance predicted variability in lane keeping as well as more collisions and increased reaction times in response to hazards. The demands of driving in general require adequate EF, particularly during the skill acquisition phase. To gain better insight into the relationship between EF and driving, it is important to examine the three component parts of the umbrella term: inhibition, working memory, and cognitive flexibility.

Inhibition. Inhibition relates to the ability to control attention, behavior, thoughts, and emotions when necessary (Diamond, 2013). An individual's capacity to react to unanticipated or novel experiences lies in their inhibition skills, which affects our self- control and automatic responses to events. Impulsivity, a subcategory of inhibition, is a widely reported symptom of individuals with ADHD. Impulsivity directly connects to driving performance as it can perpetuate risky behaviors such as unsafe driving, or inefficiently navigating through hazardous conditions. Pope et al. (2016), Ross et al. (2015), and Walshe et al. (2017), all found negative correlations between lower inhibition and higher driving errors and traffic violations. Poorer inhibitory control was found to be associated with increased odds of being pulled over and receiving a ticket, as well as overall unsafe driving performance (Pope et al., 2016; Walsche et al., 2017). For example, a relationship was found between neurotypical novice drivers who presented with decreased response inhibition and decreased hazard detection, as evidenced by increased reaction times in response to hazards and higher incidence of collisions (Ross et al., 2015).

Attention, another mechanism of inhibition, consists of two main components: selective attention, which is focusing on a specific task or subject without being distracted by extraneous stimuli, and sustained attention, which is focusing for a prolonged period of time. Both aspects of attention are critical for driving performance.

There are many contextual and situational hazards that a driver must respond to on the road, such as those caused by the physical environment (e.g., rain, road construction) and other drivers (e.g., another car cutting across lanes). A hallmark deficit present in the ADHD diagnosis is attention: "*Inattention* manifests behaviorally in ADHD as wandering off task, lacking persistence, having difficulty sustaining focus, and being disorganized" (APA, 2013, p. 61). Barkley et al. (2002), Classen and Monahan (2017), and Pope et al. (2016) all found that problems in attention were correlated to poorer driving performance, particularly when responding to stimuli in traffic. Reduced sustained attention is linked to impairments in both inhibition and working memory abilities (Walshe et al., 2017). For example, impairments in sustained attention may affect the ability to drive for prolonged periods of time or while taking monotonous routes, such as long highway sequences that require vigilance even in the absence of continual, varied stimuli. When exercising inhibition of attention, drivers are able to selectively attend to the task of interest even in the presence of extraneous stimuli. For example, drivers must maintain optimal performance of manipulating the vehicle if a police siren goes off (auditory stimulus) to ensure they are sustaining safe driving practices.

Working memory. Working memory is similar to a short-term holding tank of information so incoming stimuli can be manipulated and related to information that will come later (Diamond, 2013). Working memory allows the brain to reason accurately to the continually changing and updating information we receive, so we can accommodate our thoughts and behaviors effectively. This is important for the decision-making process. Many researchers have duplicated findings indicating that individuals with ADHD have lower working memory capacity than neurotypical people (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). In a comparative study conducted by Diamond (2005), it was suggested that in the absence of hyperactivity, impaired attention was influenced by problems in working memory such as being bored easily during routine tasks. This boredom leads to low arousal levels, which then manifests as a lack of motivation, which results in a child being unable to focus. This is contrasted to previous theories that link the core concept of distractibility with inhibition control problems, which seemed to be less impaired in individuals diagnosed with ADHD that primarily suffer from inability to attend to stimuli (Diamond, 2005). Situational variability is defined as higher severity and manifestation of symptoms while doing certain tasks (Brown, 2009). Situational variability has been found to affect individuals with ADHD particularly if the individual is not interested in the task or if it is too difficult (Brown, 2009).

Multiple researchers have described an association between poor working memory and increased occurrence of accidents, higher rates of being pulled over and receiving a ticket, and overall risky driving (Lee & Yang, 2019; Pope et al., 2016; Walshe et al., 2017). Lee and Yang (2019) suggest that those with lower working memory lose focus or daydream while engaging in activities requiring higher cognitive load, manifesting in the inability to remember relevant information and adequately perform the task. In a study done by Lee and Yang (2019), an association was found between working memory and time perception, with poorer performance on time perception tasks that may have resulted from deficits in working memory. Similarly, Knodler, Kekikoglou, Samuel, and Fitzpatrick (2017), found time perception to affect reaction time, which impacts a driver's ability to detect and react to hazards on the road. Their article also stated that participants with poor time perception also tended to get bored during driving scenarios, which correlated to increasing their speed without being aware of it (Knodler et al., 2017).

In general, drivers are required to process multiple stimuli simultaneously while weighing potential decisions on the road to safely get from point A to point B. Organizing competing stimuli on the road, using relevant information effectively to make split second decisions, and staying up-to-date with a continual provision of incoming information and stimuli are all essential tasks of an individual's working memory to stay safe on the road. When working memory is impaired, an individual may fail to integrate new incoming information or stimuli and use it to make good decisions, leading to unsafe driving behaviors.

Cognitive flexibility. Cognitive flexibility is the ability to have sound judgment and make efficient decisions related to driving performance, particularly in the presence of unusual or unexpected stimuli, or as a novice driver experiencing contextual situations for the first time (Diamond, 2013). Developing a sense of judgment allows individuals to estimate risk appropriately, manage impulsive tendencies, and make on-the-spot decisions accurately; the inability to do so can result in individuals misjudging gaps in traffic and failing to adjust their speed in hazardous conditions (Classen & Monahan, 2017). Barkley et al. (2002) and Classen and Monahan (2017) found that a lack of judgment in individuals diagnosed with ADHD was associated with less safe driving habits than the control group, who did not display deficits in judgment or decision making.

Another interconnected component skill of cognitive flexibility involves planning, which encompasses a wide variety of skills such as time management, time discrimination, and organization. Classen and Monahan (2017) emphasize that ADHD often affects planning skills, which relates to route selection, adjusting speed to driving conditions, and time management while driving. The time discrimination abilities of children with ADHD were found to be lower than their neurotypical peers, as assessed by tasks requiring sustained performance of time discrimination skills throughout (Lee & Yang, 2019). Lee and Yang (2019) were able to discern that there is a larger need for working memory on moderate and highly challenging time discrimination tasks because of its role in time perception. Time perception is important for many aspects of driving, particularly when route planning; if an individual does not have the capacity to leave at the proper time then they are more likely to speed and make risky choices while driving. Cognitive flexibility enables drivers to be adaptive in their response to environmental stimuli and events, plan out driving actions accordingly, and maintain good judgment about various obstacles a driver will inevitably encounter on the road. When a driver has poor cognitive flexibility, their ability to safely navigate unexpected challenges and obstacles likely decreases, which can lead to unsafe driving behaviors.

Executive functioning and ADHD. Overall, clinicians generally look at ADHD as an impairment in the brain's cognitive management of EF that affects a variety of intricate cognitive abilities (Brown, 2009). Difficulties in regulating alertness, sustaining effort, accessing recall, and monitoring contextual information are often stated by individuals with ADHD who say that oftentimes their emotions are difficult to control while also focusing on a task at the same time (Brown, 2009). This will inevitably affect driving performance, which often requires inhibitory control over emotions or behaviors in response to a stimulus while simultaneously attending to other tasks.

Barkley (2004) and Shechtman et al. (2009) report that the higher-level skills involved in managing the demands of driving are often impaired with the presence of an ADHD diagnosis, particularly related to increased accident frequency and traffic violations. Shechtman et al. (2009) showed impaired visual perceptual skills, attending, and orientation to the environment and other drivers all impacted the driver’s ability to negotiate turns. Narad et al. (2013) revealed a relationship between teens diagnosed with ADHD and variabilities in speed and lane positions that may be a result of decreased cognitive attending associated with distracted driving. With EF being such a crucial component of driving and an area frequently impaired in both teens and individuals with ADHD, it is a pertinent subject of concern for OT practitioners and the public. While the research on generalized EF, ADHD, and driving is extensive, less is known about the impact that sensory processing disorder has on driving ability. The next section discusses the importance of filling a gap in research evidence regarding sensory processing patterns, ADHD, and driving performance.

Sensory Processing Disorder

As explained by A. Jean Ayres (1979), a child’s ability to process and organize sensory information plays a key role in a child’s perceptions, behavior, and learning.

Unusual responses to sensory experiences can be due to dysfunction involving the registration of sensory information, its modulation, discrimination, internal organization and/or the integration of sensory input ((Sanz-Cervera, Pastor-Cerezuela, Gonzalez-Sala, Minguez, & Fernandez-Andres, 2017). Sensory processing disorders (SPD) are characterized by difficulties in responding to sensory stimuli such as impairments in detection, modulation, or interpretation of stimuli (Ghanizadeh, 2010). The three types of SPD are distinguished as: (1) sensory modulation disorders, which are characterized by an over-responsiveness and under-responsiveness to stimuli and sensory seeking as a response to the presence of sensory information, (2) sensory discrimination disorders, which affect the ability to distinguish and identify sensory input, and (3) sensorimotor integration disorders, which involve difficulty in converting sensations into motor responses (Dunn, 1997; Sanz-Cervera et al., 2017).

Sensory Processing Disorder and Attention-Deficit/Hyperactivity Disorder. Although sensory symptoms are not part of the diagnostic criteria for children with neurodevelopmental disorders, those who are diagnosed with ADHD often show impairments in conjunction with SP and higher functioning (Dunn & Bennett, 2002). SP problems in children with ADHD are more prevalent than in neurotypical children, but this area is not well studied, and this connection is not considered strong enough to be categorized as an ADHD inclusion criteria in the DSM-5 (Ghanizadeh, 2010). Dunn and Bennett (2002) showed statistically significant differences between children ages 3-15 with ADHD and children without disabilities on all 14 sections of the Sensory Profile. In all cases, children with ADHD displayed lower scores or more frequent behaviors compared to children without disabilities (Dunn & Bennett, 2002).

The way the body processes and responds to sensory input greatly affects higher-order cognitive functioning, with impairments in processing and discrimination described as over-responsiveness, under-responsiveness, low registration (lack of discrimination), and sensitivity (high discrimination). Sensory registration is crucial for driving: perceiving visual inputs such as the traffic lights changing and movement of other cars, registration of auditory inputs such as a siren, registering the amount of force a driver is applying to the break and gas pedals. All these inputs must be perceived and processed in the brain, but can cause problems for the driver if he has sensory sensitivities; for example, hearing a variety of common sounds that occur on the road (e.g. siren, horn, birds, airplane overhead, etc.) and having difficulties filtering through the sounds that causes the auditory sensory system to perseverate over one sound specifically or struggle to make sense out of the various noises occurring. These examples provide examples of how driving tasks may be complicated by sensory processing dysfunction.

While there is strong evidence that sensory processing difficulties are common among children with ADHD, it is not yet known whether sensory processing difficulties are associated with poor driving outcomes. It is reasonable to expect that sensory processing differences may impact driving abilities due to issues with praxis, planning, organizing, and unfamiliar tasks. One of the research questions this study sought to answer was whether there was a relationship between driving errors and sensory processing profiles of the participating teens.

Sensory Processing Disorders, Attention-Deficit/Hyperactivity Disorder, and Driving. Impairment of receiving and processing sensory input in ADHD may also cause inappropriate responses in different settings, as stated by Ghanizdeh (2010), which could generalize to driving scenarios as well. According to Pfeiffer et al. (2015), children with sensory processing deficits display higher levels of over-arousal than children without sensory processing deficits, possibly resulting in higher driving errors.

Nonetheless, there is a lack of evidence in the literature supporting a link between sensory processing and driving abilities requiring further research to determine a correlation. After reviewing the literature, we identified two gaps in the knowledge about teen drivers with ADHD. The first gap is the lack of specification about which areas of EF correlate with driving errors, and the second gap is whether or not sensory processing difficulties are associated with poor driving outcomes.

STISIM Drive

Computer-based simulator training has gained much attention in many areas including driving. Today, driving simulators are being used for vehicle system development, human factor studies, and other purposes because they reproduce actual driving conditions in a safe and controlled environment (Martin & Elefteriadou, 2010). A standard driving simulator being used in many studies is the STISIM Drive. The STISIM Drive is a PC-based computer simulation program and is often used in driving evaluation and treatment (Ratzon, Lunievsky, Ashkenasi, Laks, & Cohen, 2017).

The STISIM Drive uses a Microsoft SideWinder steering wheel (Microsoft Corp., Redmond, WA) with force feedback, an accelerator, and brake pedals (Ratzon et al., 2017). The STISIM Drive can be configured to simulate a variety of different scenarios to match the requirements of a particular experiment/study (Martin & Elefteriadou, 2010). Martin and Elefteriadou (2010) found the STISIM Drive to be a valid tool of measure. A study done by Ratzon et al. (2017) found the STISIM Drive to have high ecological validity. For instance, turns on the simulator can be transferred to the road when testing conditions are the same (Martin & Elefteriadou, 2010). Bedard, Parkkari, Weaver, Riendeau, and Dahlquist (2010) discovered that people's behavior on a simulator is similar to their behavior on the road. With competent validity, driving simulators can be used to measure driving errors made by individuals. Researchers can use the data retrieved from driving simulators to distinguish between safe and unsafe drivers, and to predict which individuals have a greater risk of future crash involvement (Bedard et al., 2010). By using the STISIM Drive, we hope to determine prominent driving errors made by teens with ADHD, in regard to EF and SP to encourage and enable safe driving as occupational therapists. By quantifying our results, we can potentially increase the evidential data surrounding driving errors in relation to EF and SP.

Statement of Purpose, Hypothesis and Research Questions

The purpose of this study was to contribute to the understanding of how subcomponents of EF and sensory processing impact the intensity and frequency of driving errors for teens with ADHD across as tracked on the STISIM Drive. Ultimately, we can use the information gathered from our study to assess and train novice drivers with ADHD, guiding intervention and enhancing programs for improved driving performance. According to Ratzon et al. (2017), the ability to characterize driving styles and skills of teens with ADHD before starting driver training may help with the risk factors related to driving and lead to the development of screening tools and preemptive strategies (such as special techniques for OT practitioners and special training programs for novice drivers with ADHD). Indications about how this disorder affects their ability to drive can allow for individualized treatment tailored to clients' specific deficits they experience due to their ADHD.

We hypothesized that impairments in EF and SP would relate to driving simulator errors; the null hypothesis was defined as failure to find a relationship between those factors. We anticipated that correlations would exist between lower scores in attention, higher rates of impulsivity, and elevated frequency of driving errors. Lower registration of sensory stimuli, we believed, would relate to hazard detection and response times while navigating scenarios on the STISIM Drive. Our initial hypotheses included positive correlations between attention, working memory, and driving errors based on studies by Classen and Monahan (2017), Walshe et. al (2017), and Lee and Yang (2019). We expected to see common errors in speed regulation, lane maintenance, and total driving errors (Classen, Monahan, & Hernandez, 2013, Classen, Monahan, & Wang, 2013).

The first research question we sought to answer was which specific subcomponents of EF and SP were correlated with driving errors made on a stimulator by teen drivers with ADHD. The second research question we examined was the effects that certain cognitive and sensory characteristics had on the driving performance of teens with ADHD on the STISIM Drive. Significant findings from this study may contribute to the growing body of knowledge regarding ADHD and driving, which will further catalyze other researchers to continue to investigate the issue surrounding safe driving.

Theoretical Framework

The Person-Environment-Occupation-Performance (PEOP) is described as a client-centered model that is meant to improve everyday performance of occupations that are necessary and valued by individuals, organizations, and populations. The major components in the PEOP model—person, environment, occupations, and performance—impact the development of self-identity and desire for self-fulfillment through the participation in occupations (Christiansen, Baum, & Bass-Haugen, 2005). Person includes intrinsic factors such as, physiological, cognitive, and psychological characteristics. A person's environment includes extrinsic factors such as physical, natural, cultural, and societal environments. Occupation involves what an individual wants and needs to do. Lastly, performance is the act of doing the occupation.

The PEOP model uses a transactive approach to enhance participation, with an emphasis on occupational performance. Under this model, Christiansen et al. (2005) described occupational performance as the result of the interaction between the person, environment, and occupation that ultimately enables the individual to develop a personal identity and sense of fulfillment. All individuals embody the innate volition to explore their environments and develop mastery to construct a meaningful existence that is balanced between work, play, and other occupations. Christiansen et al. (2005) categorized function as demonstrating competency to perform and master a variety of occupations that contributes to overall positive health and wellbeing. Individuals are more likely to persist through change in the clinical process and remain motivated if they perceive their occupational performance as competent and meaningful. As roles and environments shift throughout life, an individual must demonstrate resilience by adjusting and maintaining mastery within chosen occupations. Dysfunction occurs when a person's occupational performance is limited and restricted (Christiansen et al., 2005). As a result, competency will not be achieved which directly affects the quality of life for the person. Therefore, the interaction between all components can positively or negatively affect occupational performance.

The teenage years involve critical experiences associated with role exploration and creation, in which greater independence drives social engagement and facilitates identity formation (Erikson, 1980). The ability to drive is crucial for this process because it increases access to a variety of environments and opportunities. This is why we chose to frame our research study within the PEOP conceptual framework; this framework allowed us to understand the importance that driving had for teens within their lives and development of selves.

Methodology

After reviewing the literature, it was clear that there were gaps in knowledge regarding driving abilities and specific cognitive and sensory attributes of teens with ADHD. To fill this gap, we devised a study to contribute to the body of knowledge in this area. Descriptive case studies can be used to describe the particular attributes and behaviors of participants and provide insight for future research by the connections made between certain variables in the study consistent across all participants.

Procedures

A descriptive case study was conducted with four participants to examine the relationship between EF, SP, and driving errors in teens with ADHD.

Participants

Four teens participated in the study, aged between 14 and 16 years old, all with a diagnosis of ADHD. The inclusion criteria included teens with ADHD between the ages of ≥ 14 years and ≤ 18 years, 11 months; novice driving skills (up to one year of experience); visual acuity of at least 20/40 with contacts or glasses; ability to travel to Irvine, CA; and the physical ability to operate the various parts of the simulated car. ADHD is associated with a variety of comorbid conditions, such as depression and anxiety. Such comorbidities are difficult to isolate due to overlapping symptoms with ADHD. However, the exclusion criteria do not differentiate between teens with a comorbid diagnosis of depression or anxiety. Participants were accepted if they were able to participate in the questionnaires and driving simulator without distress. Teens with more than one year of driving experience, severe psychiatric conditions negatively affecting mental or physical functioning, and teens with ASD were excluded from our study. Teens with ASD were excluded from participating due to an established separate body of research specifically related to ASD and driving.

Recruitment. The teens were recruited through convenience sampling by word of mouth and flyers in public places at local communities (e.g., schools, school districts, after school programs, behavioral health clinics, doctors' offices).

Consent. Before taking part in the study, participants and their caregivers were asked to complete informed assent and consent documents, respectively informing the participants of the minimal risks involved with participation in the study. Examples of both the parent consent and teen assent forms can be found in Appendices D and E, respectively. Consent documents emphasized the right to withdraw consent during any point, or from specific aspects of the process while still maintaining the right to be involved in other consented parts of the study.

Measures

After providing consent, both the parent and youth completed a standard intake form; the parent intake form and teen driving form can be located in Appendices F and G. Parents completed the Comprehensive Executive Function Inventory (CEFI) parent report form to assess specific EF characteristics while each participant completed the Adolescent/Adult Sensory Profile (AASP), a self-questionnaire measuring sensory processing patterns and effects on functional performance. We used data from the CEFI, AASP, and STISIM Drive to determine relationships.

Comprehensive Executive Function Inventory (CEFI) parent report. The CEFI questionnaire, filled out by the parent, indicates overall functioning of the participant's executive control over cognitive abilities within the following nine domains: attention, emotional regulation, inhibitory control, initiation, planning, self-monitoring, flexibility, organization, and working memory. Each score is then cross-referenced to the overall score, which is indicative of which areas of EF are strengths and weaknesses for the person while also comparing them to norm-referenced data for individuals within theirsame age range. At the end of the scoring procedures, the scores indicate relative strengths and weaknesses in EF, the nine subsets of skills, and their percentile rank in relation to others their age. The CEFI parent report form has excellent reliability, with a strong Cronbach alpha value of .98 for internal consistency and r = .91 for test-retest reliability. The CEFI was normed on a large national scale that represented the U.S. population, which gives it excellent reliability and validity when assessing the EF of children and adolescents (Naglieri & Goldstein, 2014).

Adolescent/Adult Sensory Profile (AASP). The AASP is a self-questionnaire measuring SP patterns and effects on functional performance. This measure gives the participant values for each of the four quadrants of the AASP: low registration, sensory seeking, sensory sensitivity, and sensation avoiding. The assessment uses a 5-point Likert scale system that indicates the frequency of responses (Almost Never, Seldom, Occasionally, Frequently, Almost Always) to a variety of sensory stimuli involved in taste/smell, movement, visual, auditory, touch, and general activity level components. These values are then compared to norm-referenced data that classifies the participant’s scores as falling within average ranges or if their sensory characteristics are classified as less, more, much less, or much more than average. These scores will allow the participant to understand their personal patterns of sensory processing within typical sensory environments that affect daily functioning. The AASP is considered precise and stable, with test reliability alpha scores of the quadrants ranging from .639 to .775, with 1 indicating perfect consistency. Brown et al. (2001) found evidence supporting the reliability and validity for use of the AASP in practice settings, indicating its ability to provide a sound and appropriate evaluation to assess behavioral responses to everyday sensory experiences.

STISIM Drive. The final measure included recording errors on the driving simulator program called STISIM Drive, located at Stanbridge University in Irvine, California. The virtual reality simulation system is meant to provide a real-life experience of driving on the road in a vehicle. Its high ecological validity has allowed the STISIM-Drive to be a tool for driving evaluation and treatment for driving specialists (Bedard et al., 2010; Shechtman et al., 2009). Participants were seated in the STISIM Drive and given instructions about its use and safety procedures, ensuring each participant understood how to navigate the controls on the car, such as using the turn signal and gas pedal.

Each individual participated in one session lasting an hour and a half on the driving simulator and were told they would practice with two scenarios (practice #1 and 2) followed by three scenarios (trial #1, 2, and 3). The data collected was generated from the three scenarios (trial #1, 2, and 3). Coaching was provided during the first two practice scenarios, to be sure the drivers understood the expectations and rules of the road before beginning the recorded trials. Ultimately, the teens' driving performance was determined by the collected data related to driving errors on the final three trials using the STISIM Drive.

Driving Scenario Breakdown

The driving scenarios varied between roadway design, type and frequency of intersections, traffic density, environment, conditions, and potential hazards (Classen & Monahan, 2017). The different experiences in each scenario targeted specific skills that assessed the individual's skill set, while also providing varied modes of intervention implementation when practicing the different driving behaviors in environments that correlated to real-world situations that the individual would encounter on the road.

The first driving scenario was set in a suburban neighborhood with light oncoming traffic, an intersection, and a biker who is riding on the side of the road. This first practice scenario targets hazard detection, problem-solving, and lane maintenance skills.

The second driving scenario takes place in a city where there is two-lane traffic occurring in both directions. At one point during the drive, a parked car pulls out in front of the driver, forcing an adaptive response to maintain safety. The skills required in this scenario include response inhibition, working memory to integrate the new information regarding the car cutting the driver off, and attention.

The third scenario was the first trial that was recorded for data collection. It was set on a long, two-lane roadway with other cars on either side of the road. The driver eventually comes to a four-way crossing without a stop sign, and there are two other cars that can be seen coming towards the intersection from multiple directions. This requires the use of problem-solving, inhibitory control, decision making, and working memory.

The fourth scenario was in a small-town setting. The speed limit is set at 45 miles per hour (mph) as the car drives through the suburban area past houses and parked cars on the side of the road. At one point, there is a pedestrian seen jaywalking that the driver must try to avoid. The skills required in this scenario include flexibility, inhibitory control, working memory, and attention.

The fifth and last scenario was located again in a city, but this time requiring fast reaction times, problem-solving, and navigating a turn. The driver comes across a stoplight where they are instructed to take a left-hand turn, as indicated by a large arrow temporarily displayed on the screen accompanied by a voice stating: “At the next intersection, take a left turn.” As the driver is turning left, some people begin jaywalking across the street and the driver must successfully slow down and stop their vehicle without hitting the pedestrians or other drivers. Divided attention, visual tracking, working memory, and problem-solving were most important in navigating this scenario.

Driving Task Analyses

The different experiences embedded within each scenario targeted specific skills to assess the individual’s driving skills while also providing opportunities to practice different driving behaviors in virtual environments that correlate to real-world situations the individual will encounter on the road. Special attention was given to the contextual environment within the vehicle, such as the presence of loud stimuli, by ensuring they were only accompanied by one researcher at a time to limit distractions. Despite the varying cognitive skills required to navigate each unique scenario, it was a general assumption that all scenarios required drivers to continually visually scan and assess various tasks within each scenario, while also interpreting unsafe situations that rely on the intersection of perceptual and cognitive abilities.

When looking at even the most basic driving experiences, there are many performance skills necessary to ensure safe and appropriate performance. For example, simply stopping at a red light requires many perceptual skills and sequencing of steps, such as observing the light is red, determining that the vehicle must be stopped, and judging the space between the vehicle and those before it to stop far enough back without causing a collision (Richard, Campbell, & Brown, 2006). The driver is tasked with coordinating their cognitive interpretation of knowing when to stop while balancing it with the psychomotor component of sending that message down to your foot which will then slowly press the brake, relying on adequate proprioceptive functioning, and consequently stop the vehicle. When the light turns green, drivers must express inhibitory control when other vehicles are in front of them so they wait to press the gas pedal and proceed into the intersection safely; this also requires functioning working memory capacity.

Adding a turn within a scenario requires additional recruitment of perceptual and cognitive skills, which is complicated by the presence of additional stimuli such as pedestrians and other drivers. Activating the turn signal requires first acknowledging the need to use it after initially deciding to make a turn, when the driver must also determine how soon to engage the signal, a decision that is influenced by the judgment of space between himself and the driver or intersection located ahead of him (Richard et al., 2006). Navigation of the turn demands the use of moderate-to-heavy perceptual and cognitive skills, particularly requiring the driver to balance multiple subtasks and stimuli simultaneously. These subtasks involve checking blind spots and mirrors, judging speed of other drivers and/or pedestrians, modulating speed throughout the whole turn, and adhering to legal driving behaviors by acknowledging roadway and pavement markings (Richard et al., 2006).

In a study conducted by Richard et al. (2006), it was determined that difficult perceptual tasks involved in driving included visually following stimuli, reading symbols, and scanning to search for an object. Difficult cognitive tasks included interpreting road signs, judging gaps in traffic or safe scenarios, and navigating unexpected hazards particularly in time-pressured situations (Richard et al., 2006). Unfamiliar or unexpected events can be difficult for individuals with low flexibility, low working memory, and other EF deficits as they require the driver to respond to the hazard, decide what they should do, and effectively respond through the coordination of perceptual, cognitive, and psychomotor systems.

Utilizing the knowledge about driving analyses from these various studies previously discussed, results from the measures selectively chosen to target those factors were used to determine whether there was an association between EF, SP, and driving errors in teens with ADHD as assessed through the STISIM Drive. The goal was to identify specific aspects of EF and SP related to driving errors in order to educate families of teenagers with ADHD as well as inform future driving education programs and guide OT practitioners in treatment strategies.

Data Analysis

A descriptive case study design was used to determine the relationships between variables by descriptively summarizing all variables for each participant and the data set as a whole (e.g.., frequencies, percentages, means, and standard deviations). The STISIM Drive collected errors and was later cross analyzed with the results from the CEFI and AASP, with all assessment outcomes entered separately for use in a factor analysis in order to find relationships between data points (Taylor & Kielhofner, 2017). Data collection included frequencies of the various demographics from intake forms, EF (sub)scores, SP preferences, and driving errors. A matrix correlational analysis was created following data collection to determine which items within the demographics (from the intake forms), EF, and SP measures correlated with driving errors on each of the scenarios. The data was entered into a password-protected Statistical Package for Social Sciences (SPSS) database that would show relationships between the predetermined variables correlated against each other. In order to establish statistical significance with the data collected from the four participants, the correlation coefficient needed to be greater than $p \leq 0.1$ (v. 26, IBM, New York, U.S). Data entry was checked by each of the researchers to ensure accuracy of entry. Information derived from the standardized intake form (parent-report) was used to control for confounding variables, such as pre-existing medical diagnosis or conditions, medications, use of glasses or contacts, and level of driver education.

Research Question #1

Research question #1 was sought to answer which specific subcomponents of EF and SP were correlated with driving errors made on a stimulator by teen drivers with ADHD. Researchers assessed the strength of the relationship between the results from the CEFI and AASP to driving simulator errors using Spearman's rho to evaluate the Likert-type survey responses. Higher rho coefficients denoted a stronger magnitude of the relationship between two variables, while smaller rho coefficients denoted weaker relationships.

Research Question #2

The second research question we examined was the effects that certain cognitive and sensory characteristics had on the driving performance of teens with ADHD on the STISIM Drive. Assessment of the strength of the relationship between the results from the CEFI and the AASP to driving simulator errors was done through utilization of Pearson's r to evaluate the survey responses using two-tailed test. Higher r coefficients ($r > +/-.34$) denoted a stronger magnitude of the relationship between two variables, while smaller r coefficients ($r < +/-.34$) denoted weaker relationships. This study predicted the number of driving simulator errors made by novice teen drivers with ADHD from the multiple EF and SP variables. The report generated by SPSS articulated p-values for all coefficients in the model based on the t-statistic.

Limitations

There were three key limitations in the study that should be addressed in future research: sample size, validity of driving simulator, and comorbidities associated with ADHD.

Sample Size

The sample size of the study was small, consisting of just four participants, which is under the number needed to determine if a data set is statistically significant. Because of this, researchers use a simple case study descriptive design because this allowed for the discussion of the results of each individual case, particularly as they related to sensory and executive functioning alongside driving errors made by each participant. There is enough evidence for the small study to impact the existing literature surrounding driving errors and ADHD functioning, while still offering a unique perspective on the specific deficits associated with ADHD diagnoses and contributing to the body of knowledge prevalent within research already.

Driving Simulator

While the simulator has been shown to be a reliable and valid modality for driving assessment and training, it is not a real-life situation, and cannot completely mimic everyday driving experiences. However, based on research conducted by Classen and Monahan (2017) and Shechtman et al. (2009), the simulator still offers realistic scenarios that create valid opportunities for utilization within driving education settings.

Comorbidities

ADHD is associated with a variety of comorbid conditions, such as depression and anxiety. Although exclusion criteria did not differentiate between teens with a comorbid diagnosis of depression or anxiety, it was hypothesized that symptomatology of either condition would affect driving performance differently than a teen with only an ADHD diagnosis.

Medication

Information regarding medication usage was gathered and processed into the factor analysis to determine if it had any effect on driving errors, despite not controlling for medication use as part of the exclusion criteria while recruiting participants. There were two participants that regularly take medications, but only one who had taken their typical dosage the day she participated in the study. The half-life of Ritalin, the medication participant 2 had taken earlier that day, is only about 2.5 hours, making it unlikely that its effects were still present in the afternoon during the testing time (Food and Drug Administration [FDA], n.d.).

Ethical and Legal Considerations

Ethical approval was granted by Stanbridge's University Institutional Review Board (IRB), documented on Proposal #01930 to mitigate the risk of potential harm of the study to the participants. Consent from participants was obtained from their guardians and assent was obtained from them.

Recruitment Procedures

Participants were recruited through convenience sampling, using flyers and word of mouth, an appropriate method of recruitment according to the IRB. Researchers created a flyer containing information about the study's purpose, benefits, and incentive before beginning recruitment through word of mouth, personal connections, and community agencies serving youth with ADHD about eligible participants.

Consent Process and Minimization of Risks

There were minimal risks associated with the study, however, special considerations and precautions are warranted when working with a vulnerable population such as minors with ADHD. Children lack the autonomy and decision-making capacity to ethically and legally consent to participate and fully understand and assume the risks of research. Because children under the age of 18 participated in the study, they required special protections. Special attention was given to the confidentiality of the information, mitigating risks associated with a breach of confidentiality through use of a number system to identify each participant. Participants were given a teen assent form to sign after they were explained the procedures to ensure they understood the reason for their participation. Parents were also given a comprehensive consent form for the same reason. In order to further mitigate risks with this youth population, researchers provided them multiple ways and times throughout the study to opt out if needed by periodically checking in with each participant and watching for their non-verbal communication as well.

Driving Simulator as an Assessment Tool. There were three issues to consider when utilizing driving simulation as an assessment tool. The first issue was the potential for the simulator to provide a false sense of security and confidence because the driver knows no repercussions exist within the simulator scenarios for unsafe driving efforts. While the simulator has been shown to be a reliable and valid tool for driving assessment and training, it is not a real-life situation, in which it cannot completely mimic everyday driving experiences. However, based on research conducted by Classen and Monahan (2017) and Shechtman et al. (2009), the simulator still offers realistic scenarios that create valid opportunities for utilization within driving education settings. Thus, it is plausible that the skills learned through simulator training can be transferred to on-road performance.

Motion Sickness. The last issue is that driver simulation has the potential to cause motion sickness in the simulator, especially for older adults. To address this issue, participants were instructed to let us know if they were feeling sick so we can stop the trials. Challenges can arise when attempting to evaluate partial or complete results for an individual who became sick during the assessment or deciding when to stop the driving simulation when a participant does experience simulator sickness. To avoid these potential risks, bibliotherapy was provided before the session to the parents and participants. We also provided information about the driving simulator tool along with knowledge of the possibility of simulator sickness. Participants experiencing symptoms at any time during the simulation had the right to end the assessment without the risk of losing incentives.

Discouragement from Errors. To mitigate potential feelings of discouragement after committing driving errors on the simulator, we ensured that teens were welcomed into an encouraging atmosphere that emphasized a strengths-based approach without emphasizing errors made. It was imperative for us to evaluate participants’ false sense of security and confidence using the simulator, so that they understood the nature of the research and what they were participating in without them believing the simulator situations were real-life. We were aware that parents and caregivers may also feel discouraged by teen driving errors and driving statistics provided on the ADHD information sheet, so we continually promoted the strengths-based approach when discussing the study with participants’ parents as well. Furthermore, we also provided driving tips and praise throughout the two practice scenarios, and during the driving practice following data collection to ensure the participants' self-esteem and self-efficacy was upheld throughout the process.

To ensure all ethical and legal considerations were given adequate attention, we gained informed consent from the following parties: institutional consent from Stanbridge University, parental consent from the parents of participants, and the assent of the participants (minors). We emphasized that we are in no way associated with the Department of Motor Vehicles (DMV) nor providing driving instruction. Participants received supplemental driving practice on the simulator only. We also communicated to each participant that if there were any parts of the process that they felt uncomfortable with, they could choose to withdraw consent at any point. Participants were also informed that they were able to withdraw consent for specific aspects of the study while still continuing with other aspects they consented to. Researchers made sure that the participants understood their rights throughout the study. If participants had any further questions regarding the study, we provided our contact information, as well as our advisor's contact information. Costs to participants included the necessity to travel to Stanbridge University for the study and the time it took to complete the session.

Costs to Participants

There were minimal costs to the participants involved in the session. However, parents needed to transport their children to Stanbridge University and willfully spend an hour and a half to complete the assessment. Overall, participants agreed to dedicate their time to partake in our study.

Reimbursement and Compensation to Participants

At the end of each session, we provided educational material to the parents or caregivers about preventing driving errors, additional resources for driver education, and encouragement regarding the prevalence of driving mistakes and how to most effectively learn from them. At the conclusion of the study, we provided a generalized Fact Sheet on ADHD and Driving. The handout we provided included information regarding risks, certified driving rehabilitation specialists, and recommended websites as additional resources on ADHD and available driving training programs. Each participant also received a gift card containing $10 and 30 minutes of guided practice on the driving simulator at the end of the study as a token of our appreciation. We offered a minimal incentive to mitigate for the cost of time and participation.

Confidentiality of Records

We maintained the confidentiality of information collected from research participants by securely storing data obtained from the participants (e.g., completed questionnaire, consent forms, assessments results) that could only be accessed by the researchers and storing all paper information in a locked room in the occupational therapy department at Stanbridge University. Confidentiality was maintained throughout the study by initially providing each participant with a number that respectively corresponded with their labeled paperwork. Once everything was numbered, the master sheet with their names/numbers was kept locked and separate from all of the numbered forms to protect their identities.

Results

To begin interpreting the data, each participant was analyzed to determine significant within-ground statistical information. Each participant was profiled to determine if any initial patterns or relationships between data points were obvious, before bringing the data together between all four participants. The overall findings indicate significant variability in EF, SP patterns, and driving errors among participants. The participants as a whole scored very low on EF domains, but their scores varied among the nine different components measured by the CEFI. No pattern emerged between sensory processing patterns and driving errors, or between the sensory processing patterns and participants themselves. As each participant is analyzed individually to determine her executive functioning strengths/weaknesses, SP patterns, and specificity of driving errors, it can be organized between each other to look for commonalities between specific EF and driving errors.

Participant 1

Participant 1 was a 16-year-old female with ADHD that was being treated with Vyvanse, which she did not take the day of the study. She has not started driver's education courses yet but reports she has taken most of her classroom driver's education course several months prior. She is moderately interested in driving but not very confident in her ability, ranking her interest and confidence as a 3/5 and 2/5 respectfully. She estimates that she plays about two hours of video games a week.

Throughout the trials, participant 1 did not exceed the speed limit in any of the three trials and appeared cautious and careful throughout. She had two total road excursions, once in Trial #1 and the other in Trial #2. She did not have any road excursions in her third and final driving scenario. Participant 1 stayed within her lane for the entirety of all three recorded trials, receiving a score of 0 on the total center line crosses. She had one total collision in Trial #1.

Participant 1 was the only teen in the study with AASP results indicating "similar to most people" across all domains.

The overall CEFI score indicated that participant 1's executive functioning is in the low average range, at the 16th percentile. Her biggest strength was in inhibitory control, falling within the average range, in the 42nd percentile. Relative weaknesses indicated by the CEFI were attention, flexibility, initiation, self-monitoring, and working memory. Out of those scores, attention was the lowest, at 8th percentile, below average for the population. These scores are consistent with the scores from the other three participants, except her weakness in flexibility that fell within the "Low Average" range of the CEFI.

Participant 2

Participant 2 was a 15 years and 2-months old female with ADHD who was taking Ritalin and Prozac medication, which she took the day of the study. She has not started driver's education and is moderately interested in driving, but not confident in her ability to do so, ranking her interest and confidence as a 3/5 and 0/5 respectfully. She estimated that she played about 15 hours of video games a week.

Throughout all three trials, participant 2 adhered to all speeding regulations, maintaining appropriate speed throughout all three sessions and was very cautious throughout. Participant 2 had a total of one road excursion that was recorded during Trial #1. This participant had no center line crossings as she managed to stay within the lines during all three trials. Participant 2 had a total of one collision, occurring during the first trial. Lastly, participant 2 was able to attend to all the stop signs throughout the session for a recorded total of 0 missed stops.

The AASP indicated that Participant 2 had sensory processing patterns “similar to most people” in sensory sensitivity and low registration but “less than most people” in sensory seeking and sensory avoiding.

The overall CEFI score indicated that participant 2’s executive functioning is in the below average range, at the 7th percentile. Her biggest strength was in flexibility, falling within the average range at the 34th percentile. The relative weaknesses indicated by the CEFI were initiation, organization, self-monitoring, working memory, planning, and attention. Out of those scores, initiation was the lowest, at the 1st percentile, determining that it is well below average for the population. The scores are consistent with the other three participants.

Participant 3

Participant 3 was a 14-year-old female with ADHD who was currently not taking any medications. She has never driven nor has she started taking any driver’s education courses. She reports being moderately interested in driving but not confident in her driving skills which ranks her interest and confidence at 3/5 and 0/5 respectively. Participant 3 estimated that she played about 35 hours of video games a week.

Throughout the three trials, Participant 3 had two speeding regulations, one during Trial #1 and another during Trial #3. Participant 3 had a total of 5 road excursions, all occurring in Trial #1. There were two instances of centerline crossings that occurred during Trial #1 and #2. Participant 3 had a total of four collisions, with three collisions occurring during Trial #1 and one during Trial #3. Lastly, Participant 3 was able to attend to all the stop signs throughout each of the trials.

The AASP indicated that Participant 3 had sensory processing patterns “similar to most people” in sensation seeking and sensation avoiding. In the sensory sensitivity domain, participant 3 showed patterns described as “more than most people” and “much more than most people” in low registration.

The overall CEFI score indicated that participant 3’s executive functioning is in the low average range, at 9th percentile. Her biggest strength was in flexibility, falling within the high average range at 81st percentile. The relative weaknesses indicated by the CEFI were emotional regulation, self-monitoring, attention, organization, inhibitory control, and working memory. Out of those scores, inhibitory control and working memory were the lowest in the 1st percentile, determining that it is well below average for the norm-referenced population. These scores are consistent with the scores from the other three participants, except for her strength in flexibility and initiation.

Participant 4

Participant 4 was a 14 years and 9-month-old female with ADHD inattentive subtype who was not taking any medications at the time of the study. She had not started driver’s education courses yet, and indicated that she was extremely interested in driving but lacked confidence in her ability, as she ranked her interest as a 5/5 and confidence as 3/5 respectively. She estimated that she plays 1 hour of video games a week.

Throughout the three trials, Participant 4 had 0 missed stops, road excursions, and collisions. Participant 4 had moderate center line crosses during the first trial but maintained proper lane adherence during the final two Trials. Although she adhered to the speed limit during Trial #1, she significantly increased her speeding during Trials #2 and

#3. This could indicate that Participant 4 was more cautious, rather than comfortable, during the initial trial and gradually became more comfortable as she increased her speed during the last two trials.

The AASP indicated that she had sensory processing patterns “similar to most people” in sensation seeking. In sensory sensitivity and sensory avoiding, Participant 4 showed patterns that are “more than most people” and showed processing patterns “much more than most people” in low registration.

The overall CEFI score indicated that participant 4’s executive functioning is in the low average range, at 13th percentile. However, her biggest strength was in organization, falling within the average range at the 34th percentile. The relative weaknesses indicated by the CEFI was emotional regulation, attention, planning, working memory, and initiation. Out of those scores, planning, working memory, and initiation were the lowest at the 7th and 8th percentile, determining that it is below average for the population. These scores are consistent with the scores from the other three participants, except for her strength in organization.

Overview of Within Group Results

There were few driving errors overall, which were generally spread across road excursions, center line crossings, speeding, and collisions. All participants had decreasing driving errors throughout, except one whose speeding increased. All participants had low average or below-average overall CEFI scores. Each participant had low average or below average attention, planning, and working memory (see Table 5). Notably, three participants had relative strengths in inhibitory control. There was no observable pattern in sensory processing patterns between participants. Notably, none of them had sensory seeking patterns. Two participants had both low registration and sensory sensitivity.

Overall, no observable relationships or patterns were established between specific aspects of EF, sensory processing patterns, or driving errors. Statistical analysis was used to further investigate the relationships between these factors.

Between Group Data Results

After synthesizing the data, averages of each error were determined and compared to each of the participants' values. The first two participants did not speed, but the last two exceeded the speed limit for a total of 5.5% and 24.9% of the time respectfully. There were eight road excursions committed between all four participants, with the average being two per participant. Center line crossings were observed in two out of the four participants, with them averaging 10.6% and 6.4% of the time respectfully. There were a total of six collisions, with each participant experiencing at least one, except for the last participant. All four participants missed many turns signals, which we did not include in our data analysis. We felt that the errors reflected the participants' inept habit of using a turn signal as opposed to EF skills. Refer to Table 1 for a list of all driving errors.

Initially, we ran a factor analysis and component matrices on the scores from the CEFI from all participants. This showed a strong relationship between emotional regulation, flexibility, inhibitory control, initiation, and working memory, accounting for 81% of the variance in data as determined by the Eigenvalues and extraction sums of squares loadings. Of the four participants, three showed emotional regulation and flexibility as strengths and all four were strong in inhibitory control. Three participants had poor initiation and all four scored low on working memory. The Cronbach's Alpha reliability was very good at .93. What this shows us is that there is a relationship between high emotional regulation, flexibility, and inhibitory control with low initiation and working memory. When looking at the factor analysis (see Table 2), there is a strong relationship between flexibility and working memory with a critical value of -.954, and also with inhibitory control and working memory with a correlation coefficient of .975. Self-monitoring and organization are also highly related, with the correlation coefficient of .966 between them.

The component matrix also showed a relationship between attention, organization, and self-monitoring with an Eigenvalue indicating that this group of variables accounted for 10% of the variance in data. See Table 3 for the components.

In our second factor analysis, we found a relationship between flexibility, initiation, working memory, and center line crossing on the simulator. This accounted for a large part of the variance in data. The results also showed a connection between interest in driving, driving confidence, video game participation, speed, excursions, collisions, attention, organization, planning, and self-monitoring. The Cronbach's Alpha showed fair reliability at .62 for this data set. The factor analysis table most notably described correlations between speeding and interest in driving (.976) and excursions with collisions (.980).

Table 4 used correlation coefficients to measure the relationship between two variables with a significant relationship between variables (p-value $\leq$.01). We found that driving errors and executive functioning components had a high correlation coefficient in four areas. There was a positive association between collisions and initiation (.929), collisions and flexibility (.944), center line crossing and low registration (.941), and road excursions and initiation (.946). The results found positive associations between interest in driving and attention (.930), self-monitoring (.965), and speeding (.976). A positive association between confidence in driving and self-monitoring was also found with a correlation coefficient of .912.

Overall findings from the AASP revealed differences across all quadrants for each of the participants. Each individual has their own sensory profile and unique SP patterns that may impact participation differently across different environments. However, in two out of the four participants, we noticed higher scores on low registration and sensory sensitivity, along with higher driving errors on the simulator, which may be due to experiencing greater discomfort in response to sensory stimuli, slower response time, or not noticing sensory stimuli. Our results showed a positive association between sensory sensitivity and center line crossing with a correlation coefficient of .952 which we found to be true for participant 3.

Overall, participants in our study exhibited low EF and differences in SP which is consistent with the literature findings indicating that EF is often impaired in individuals with ADHD and may lead to a higher incident of driving errors and accidents (Classen, Monahan, & Wang, 2013; Classen, Monahan, & Brown, 2014; Pope et al., 2016).

Discussion

In our research study, we examined the effects of ADHD symptomatology on teen drivers as assessed by the STISIM Drive. With the employment of the PEOP model within our research study, we were able to detect the various implications that ADHD symptomatology has on the individual and the multiple components involved in driving (the occupation).

Generally, experienced drivers are able to exhibit lane maintenance on a straight road, stimuli adjustment, vehicle positioning, speed control, and visual scanning without conscious thought (Winter, Monahan, & Pierce, 2017) However, the participants from our study had difficulties with these skills, pointing towards their novice driving ability that may be affected by ADHD symptomatology. Consistent with our findings, Lee and Yang (2019) found individuals with low working memory, such as all four participants in our study, lose focus during activities requiring high cognitive load (e.g., new driving situations) that results in their inability to remember all relevant information. Working memory is a critically important element for the ability to juggle scenarios with multiple stimuli intersecting at the same time. With low working memory, our participants' exhibited difficulty staying within their lanes, particularly during busier driving scenarios.

At the same time, our participants had relatively high inhibitory control, in relation to overall EF scores, which generally represents inhibitory control of attention that Diamond (2013) terms interference control. Their ability to selectively attend to the task improved in later trials, after they were able to experience the different types of stimuli they would be exposed to. This may represent their higher ability to control attention, although their capacity for working memory is so little.

The results from our factor analysis also point to a strong positive correlation between working memory and inhibitory control, which is seen also from other studies namely ones produced by Diamond (2013) and Ross et al. (2015). Decreased inhibition and working memory have been found to be related to lane keeping, which our study corroborated when looking at center lane crossings and excursions (Ross et al., 2015).

In our case study, participant #2 had the lowest overall EF score, but also made the fewest errors on the driving simulator. This finding contradicts existing literature and is likely idiosyncratic but may indicate that teens with lower EF skills may compensate for lack of cognitive control and drive more cautiously to avoid unsafe driving situations. However, more data and research need to be done to determine if a correlation exists.

Additionally, studies have also shown that teens with ADHD have SP difficulties, but with no clear pattern related to poor driving outcomes (Dunn & Bennett, 2002). Three out of the four participants in our study displayed SP differences with no specific pattern indicating poorer driving outcomes, but they did commit driving errors. Although we were not able to establish statistical significance, the two participants who reported very low registration and high sensitivity on the AASP also had more center line crossings and speed occurrences than the other two participants. These findings constitute further investigation between the 2 variables to examine a potential relationship. Interestingly, none of our participants scored high in the sensory seeking pattern as might be thought of in teens with ADHD. This is a potential new finding and an area that should be further studied.

Lastly, all participants increased in driving accuracy with successive simulator practice, with the exception of one increased speeding incidence from participant #4. This was possibly due to increased confidence on the simulator. Consistent with the literature, extensive practice and repetition is recommended to develop more automatic control and safe driving habits.

Conclusion

In this descriptive case study, we sought to identify the effects of ADHD symptomatology on teen drivers through the STISIM Drive. Our results implied deficits in executive functions have a direct impact on driving performance, particularly for novice teen drivers. Although our research questions were not thoroughly answered, similar to existing literature, our data indicated promising evidence that teens with ADHD can be successful in the occupation of driving through continued practice and improvements in EF skills. Similarly, Classen and Monahan (2017) found evidence that supports the use of a driving simulator to assess driving performance of teens across various diagnostic categories, particularly with teens with ADHD. They also found that it is feasible for healthcare practitioners to further research the use of a driving simulation practice for driving rehabilitation specifically for this population (Classen & Monahan, 2017).

Strong evidence exists for improvements in EF through various activities, such as traditional martial arts, two school curricula, and computer-based training (Diamond, 2012). Through our small research study, we noted a positive trend with slight improvements in driving errors using the driving simulator. The amount of errors decreased through each progressive trial for all four participants within one short practice session. According to Diamond (2012), youth with poorer EF benefit more from training and exhibit better outcomes with repeated practice. Studies conducted by Diamond (2012) and Diamond and Ling (2016) suggest that specific computer-based programs that incorporate some level of physical activity can improve children's EF and increase motivation to participate in these programs, catalyzing even greater improvements in targeted EF skills. With greater understanding about the particular areas that children and teens are strong and weak in, we can use that information to target individualized training and interventions to ensure greater growth in the areas they need it most.

The results of our study implicate the need for future work. First, further research with a larger sample size is needed to determine a stronger correlation between continued practice and improvement of EF skills. Second, we found a few themes within the areas of EF, SP, and driving errors in our study that are similar across past literature. All of our participants exhibited low attention, working memory, initiation, and planning, and exhibited a variety of driving errors during the driving simulation. Similarly, three out of four of our participants exhibited differences in SP, with driving errors made. We presumed low registration and sensitivity may be associated with centerline crossings, but future work is needed to determine a correlation. Nonetheless, in agreement with past literature, we were unable to connect statistical significance between the aspects of EF, SP, and driving errors, but our findings support an avenue for further investigation in this area particularly attention, working memory, initiation, planning, low registration, and sensitivity.

In general, findings from our study and the literature point towards the importance of individualized consideration due to the involvement of many EF skills and the complexities of the driving task. Therefore, we must view each individual holistically while also analyzing their unique component skills. Conducting individualized as well as pre-driving assessments with evaluation of EF and SP is crucial to best assess an adolescent's driving readiness. Further implications for OT practice to promote ADHD and driving include collaboration among pediatric OTs and Certified Driving Rehabilitation Specialists (CDRS) to share information and learn from each other, encourage practice and repetition to increase automaticity, and provide education for both teens and parents. By enlightening more effective and safe driving practices for teens with ADHD, we will be enabling higher levels of independence that lead to greater involvement in a variety of occupations in desired environments.

References

American Occupational Therapy Association. (n.d). *Driving evaluations by an occupational therapist*. Retrieved from https://www.aota.org/Practice/Productive-Aging/Driving/Clients/Evaluate/Eval-by-OT.aspx

American Occupational Therapy Association. (2016). *Vision 2025*. Retrieved from https://www.aota.org/AboutAOTA/vision-2025.aspx

American Occupational Therapy Association. (2017). Occupational therapy practice framework: Domain & process. *American Journal of Occupational Therapy*, *68*(S1-48). doi: 10.5014/ajot.2014.682006

American Psychiatric Association. (2013). *Diagnostic and statistical manual for mental disorders* (5th ed.). Washington, DC: Author.

Ascone, D., Lindsey, T., & Varghese, C. (2009). *Fatal crashes involving young drivers. Traffic Safety Facts*. Retrieved from http://www.nrd.nhtsa.dot/gov/Pubs/811218.pdf

Ayres, A. J. (1979). *Sensory integration and the child*. Los Angeles, CA: Western Psychological Services.

Barkley, R. A. (2002). Major life activity and health outcomes associated with attention-deficit/hyperactivity disorder. *Journal of Clinical Psychiatry*, *63*(suppl 12), 10-15.

Barkley, R. (2004). Driving impairments in teens and adults with attention-deficit/hyperactivity disorder. *Psychiatric Clinics of North America*, *27*, 233-260. doi: 10.1016/S0193-953X(03)00091-1

Barkley, R., Murphy, K., Dupaul, G., & Bush, T. (2002). Driving in young adults with attention deficit hyperactivity disorder: Knowledge, performance, adverse outcomes, and the role of executive functioning. *Journal of the International Neuropsychological Society, 8*(5), 655-672. doi: 10.1017/S1355617702801345

Bedard, M., Parkkari, M., Weaver, B., Riendeau, J., & Dahlquist, M. (2010). Assessment of driving performance using a simulator protocol: Validity and reproducibility. *American Journal of Occupational Therapy, 64*(2), 336–340. doi: 10.5014/ ajot.64.2.336

Ben-Sasson, A., Carter, A. S., & Briggs-Gowen, M. J. (2009). Sensory-over-responsivity in elementary school: Prevalence and social-emotional correlates. *Journal of Abnormal Psychology, 37*, 705-716. doi: 10.1007/s10802-008-9295-8.

Brown, T. E. (2009). ADD/ADHD and impaired executive function in clinical practice. *Current Attention Disorder Reports 1*(37). doi: 10.1007/s12618-009-0006-3

Brown, C., Tollefson, N., Dunn, W., Cromwell, R. & Filion, D. (2001). The adult sensory profile: Measuring patterns of sensory processing. *American Journal of Occupational Therapy, 55*(1), 75-82. doi: 10.5014/ajot.55.1.75

Centers for Disease Control and Prevention. (2015). *Leading causes of death reports, national and regional, 1999-2015*. Retrieved from https://webappa.cdc.gov/ sasweb/ncipc/leadcaus10_us.html

Christiansen, C. H., Baum, C. M. & Bass-Haugen, J. (2005). *Occupational therapy: Performance, participation and well-being* (3rd edition). Thorofare, NJ: SLACK incorporated.

Classen, S., & Monahan, M. (2017). Simulated driving performance of teens with developmental disorders. In S. Classen (Ed.), *Driving simulation for assessment,* *intervention, and training: A guide for occupational therapy and health care professionals*. (pp. 157-170). Bethesda, MD: AOTA Press.

Classen, S., Monahan, M., & Brown, K. (2014). Indicators of simulated driving skills in adolescents with attention deficit hyperactivity disorder. *The Open Journal of* Occupational *Therapy*, *2*(1). doi: 10.15453/2168-6408.1066

Classen, S., Monahan, M., & Hernandez, S. (2013). Indicators of simulated driving skills in adolescents with autism spectrum disorder. *The Open Journal of Occupational Therapy*, *1*(4), 1-13. doi: 10.15453/2168-6408.1051

Classen, S., Monahan, M., & Wang, Y. (2013). Driving characteristics of teens with attention deficit hyperactivity and autism spectrum disorder. *American Journal of Occupational Therapy*, *67*(6), 664-673. doi: 10.5014/ajot.2013.008821

Curry, A. E., Metzger, K. B., Pfeiffer, M. R., Elliott, M. R., Winston, F. K., & Power, T. J. (2017). Motor vehicle crash risk among adolescents and young adults with attention-deficit/hyperactivity disorder. *JAMA Pediatrics*, *171*(8), 756-763. doi: 10.1001/jamapediatrics.2017.0910

Diamond, A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention/hyperactivity disorder (with hyperactivity). *Development and Psychopathology, 17*(3), 807-25. doi: 10.1017/S0954579405050388

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current directions in psychological science*, *21*(5), 335–341. doi: 10.1177/0963721412453722

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34-48. doi: 10.1016/j.dcn.2015.11.005

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*, 135–168. doi: 10.1146/annurev-psych-113011-143750

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and Young Children 9*(4): 23-25. doi: 10.1097/00001163-199704000-000005

Dunn, W., & Bennett, D. (2002). Patterns of Sensory Processing in Children with Attention Deficit Hyperactivity Disorder. *OTJR: Occupation, Participation and Health*, *22*(1), 4–15. doi: 10.1177/153944920202200102

Erikson, E. H. (1980). *Identity and the Life Cycle.* New York, NY: W. W. Norton & Co.

Food and Drug Administration. (n.d.). *Ritalin LA*. Retrieved from: https://www.accessdata.fda.gov/drugsatfda_docs/label2010/021284s010lbl.pdf

Fischer, M., Barkley, R., Smallish, L., & Fletcher, K. (2007). Hyperactive children as young adults: Driving abilities, safe driving behavior, and adverse driving outcomes. *Accident Analysis and Prevention*, *39*(1), 94-105. doi: 10.1016/j.aap.2006.06.00

Ghanizadeh, A. (2010). Sensory processing problems in children with ADHD, a systematic review. *Psychiatry investigation*, *8*(2), 89–94. doi:10.4306/pi.2011.8.2.89

Jerome, L., Segal, A., & Habinski, L. (2006). What we know about ADHD and driving risk: A literature review, meta-analysis and critique. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *15*(3), 105–125. doi: 10.1007/s00787-006-0506-y5

King, J. A., Colla, M., Brass, M., Heuser, I., & Von Cramon, D. (2007). Inefficient cognitive control in adult ADHD: Evidence from trial-by-trial Stroop test and cued task switching performance. *Behavioral and Brain Functions*, *3*(42). doi:10.1186/1744-9081-3-42

Knodler, M., Kekikoglou, A., Samuel, S., & Fitzpatrick, C. (2017). *Examining distracted drivers' underestimation of time and overestimation of speed.* Retrieved from http://safersim.nads-sc.uiowa.edu/final_reports/UM%205%20Y3_FinalReport.pdf

Lee, H., & Yang, E. (2019). Exploring the effects of working memory on time perception in Attention Deficit Hyperactivity Disorder. *Psychological Reports*, *122*(1), 23-35. doi: 10.1177/0033294118755674

Mäntylä, T., Karlsson, M. J., & Marklund, M. (2009). Executive control functions in simulated driving. *Applied Neuropsychology, 16*(1), 11-18. doi: 10.1080/09084280802644086

Martin, B. B., & Elefteriadou, L. (2010). Driver behavior and advanced driver assistance systems: An exploratory driving simulator study. *Advances in Transportation Studies,* 79-88. doi: 10.4399/97888548416598

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with Attention-Deficit/Hyperactivity Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(4), 377-84. doi: 10.1097/01.chi.0000153228.72591.73

McKnight, A. J., & McKnight, A. S. (2003). Young novice drivers: Careless or clueless? *Accident Analysis & Prevention*, *35*(6), 921-925. doi:10.1016s0001-4574(02)00100-8

Murphy, K. R., & Barkley, R. A. (1996a). Attention deficit hyperactivity disorder adults: Comorbidities and adaptive impairments. *Comprehensive Psychiatry, 37*(6), 393-401. doi: 10.1016/s0010-440x(96)90022-x

Murphy, K. R., & Barkley, R. A. (1996b). Prevalence of DSM-IV symptoms of ADHD in adult licensed drivers: Implications for clinical diagnosis. *Journal of Attention Disorders*, *1*(3), 147-161. doi: 10.1177/108705479600100303

Naglieri, J. A., & Goldstein, S. (2014). Using the comprehensive executive function inventory (CEFI) to assess executive function: From theory to application. In S. Goldstein & J.A. Naglieri (Eds.), *Handbook of executive functioning* (pp. 223-244). New York, NY: Springer Science + Business Media.

Narad, M., Garner, A. A., Brassell, A. A., Saxby, D., Antonini, T. N., O'Brien, K. M., . . . Epstein, J. N. (2013). Impact of distraction on the driving performance of adolescents with and without attention-deficit/hyperactivity disorder. *JAMA Pediatrics*, *167*(10), 933-938. doi: 10.1001/jamapediatrics.2013.322

National Institute of Mental Health. (2011). *Attention deficit hyperactivity disorder.* Retrieved from http://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-disorder/complete-index.shtml

Pfeiffer, B., Daly, B. P., Nicholls, E. G., & Gullo, D. F. (2014). Assessing sensory processing problems in children with and without attention deficit hyperactivity disorder. *Physical and Occupational Therapy in Pediatrics, 35*(1), 1-12. doi: 10.3109/01942638.2014.904471

Pope, C., Ross, L., & Stavrinos, D. (2016). Association between executive function and problematic adolescent driving. *Journal of Developmental and Behavioral Pediatrics, 37(*9), 702-711. doi: 10.1097/DBP.0000000000000353

Ratzon, N. Z., Lunievsky, E. K., Ashkenasi, A., Laks, J., & Cohen, H. A. (2017). Simulated driving skills evaluation of teenagers with attention deficit hyperactivity disorder before driving lessons. *The American Journal of Occupational Therapy, 71*(3), 1-8. doi: 10.5014/ajot.2017.020164

Richard, C. M., Campbell, J. L., & Brown, J. L. (2006). *Task analysis of intersection driving scenarios: Information processing bottlenecks*. Retrieved from https://www.fhwa.dot.gov/publications/research/safety/06033/06033.pdf

Ross, V., Jongen E., Brijs, T., Ruiter, R., Brijs, K., & Wets, G. (2015). The relation between cognitive control and risky driving in young novice drivers. *Applied Neuropsychology: Adult, 22(*1), 61–72. doi: 10.1080/23279095.2013.83895

Royall, D. R., Lauterbach, E. C., Cummings, J. L., Reeve, A., Rummans, T. A., Kaufer, D. I., . . .Coffey, C. E. (2002). Executive control function: A review of its promise and challenges for clinical research [Report]. *The Journal of Neurosciences, 14*(4), 377-405. doi: 10.1176/jnp.14.4.377

Sanz-Cervera, P., Pastor-Corezuela, G., González-Sala, F., Tárraga-Minguez, R., & Fernández-Andrés, M.I., (2017). Sensory processing in children with Autism Spectrum Disorder and/or Attention Deficit Hyperactivity Disorder in the home and classroom contexts. *Frontiers in Psychology, 8*: 1772. doi: 10.3389/ fpsyg.2017.01772

Scaffa, M. E., & Reitz, S. M. (2014). *Occupational therapy in community-based practice settings* (2nd ed.). Philadelphia, PA: F.A. Davis Company.

Shechtman, O., Classen, S., Awadzi, K., & Mann, W. (2009). Comparison of driving errors between on-the-road and stimulated driving assessment: A validation study. *Traffic Injury Prevention, 10*(4). 379-385. doi: 10.1080/15389580902894989

Taylor, R. R., & Kielhofner, G. (2017). *Research in occupational therapy: Methods of inquiry for enhancing practice* (2nd ed.). Philadelphia, PA: F.A. Davis Company.

Transport Canada. (2013). *Canadian motor vehicle traffic collision statistics 2013.* Retrieved from https://www.tc.gc.ca/media/documents/roadsafety/ cmvtcs2013_eng.pdf

Walshe, E. A., McIntosh, C. W., Romer, D., & Winston, F. K. (2017). Executive function capacities, negative driving behavior and crashes in young drivers. *International Journal of Environmental Research and Public Health, 14*(11): 1-16. doi: 10.3390/ijerph14111314

World Health Organization. (2015). *Global status report on road safety 2015.* Retrieved from http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/

Appendices

Appendix A

Data Tables

Table 1: Raw data of driving errors committed on simulator, per participant.

Participant 1	Participant 2	Participant 3	Participant 4
Speeding (% of time) Trial 1: 0% Trial 2: 0% Trial 3: 0% *Average:* 0% **Road Excursions** Trial 1: 1 Trial 2: 1 Trial 3: 0 *Total:* 2 **Center Line Crossings** (% of time) Trial 1: 0% Trial 2: 0% Trial 3: 0% *Average:* 0% **Collisions** Trial 1: 1 Trial 2: 0 Trial 3: 0 *Total:* 1	**Speeding** (% of time) Trial 1: 0% Trial 2: 0% Trial 3: 0% *Average:* 0% **Road Excursions** Trial 1: 1 Trial 2: 0 Trial 3: 0 *Total:* 1 **Center Line Crossings** (% of time) Trial 1: 0% Trial 2: 0% Trial 3: 0% *Average:* 0% **Collisions** Trial 1: 1 Trial 2: 0 Trial 3: 0 *Total:* 1	**Speeding** (% of time) Trial 1: 7.2% Trial 2: 0% Trial 3: 9.3% *Average:* 5.5% **Road Excursions** Trial 1: 5 Trial 2: 0 Trial 3: 0 *Total:* 5 **Center Line Crossings** (% of time) Trial 1: 28.6% Trial 2: 3.3% Trial 3: 0% *Average:* 10.6% **Collisions** Trial 1: 3 Trial 2: 0 Trial 3: 1 *Total:* 4	**Speeding** (% of time) Trial 1: 0% Trial 2: 6.9% Trial 3: 54.3% *Average:* 24.9% **Road Excursions** Trial 1: 0 Trial 2: 0 Trial 3: 0 *Total:* 0 **Center Line Crossings** (% of time) Trial 1: 19.1% Trial 2: 0% Trial 3: 0% *Average:* 6.4% **Collisions** Trial 1: 0 Trial 2: 0 Trial 3: 0 *Total:* 0
Total Errors: 3	**Total Errors:** 2	**Total Errors:** 12	**Total Errors:** 3

Table 2: Significant relationships between CEFI subcomponents, with p-value ≤ 0.1.

CEFI component	CEFI component	Critical Value
Flexibility	Working memory	-.954
Inhibitory control	Working memory	.975
Organization	Self-monitoring	.966

Table 3: Component matrix between CEFI subcomponents, depicting multi-factorial relationships and their Eigenvalues as the percent variance in data.

Component	Percent variance
Component 1: Emotional regulation Flexibility Inhibitory control Initiation Working memory	81%
Component 2: Attention Organization Self-monitoring	10%
Component 3: Planning	9%

Table 4: Significant relationships between components of the CEFI, AASP, driving intake form and driving errors with p-value ≤0.1.

Component	Component	Correlation Coefficient
Low registration	Sensory Sensitivity	0.999
Video games played/week	Flexibility	0.988
Confidence in driving	Organization	0.982
Road excursions	Collisions	0.980
Interest in driving	Speeding	0.976
Inhibitory control	Working memory	0.975
Organization	Self-monitoring	0.966
Interest in driving	Self-monitoring	0.965
Flexibility	Working memory	-0.954
Center line crossings	Sensory sensitivity	0.952
Road Excursions	Initiation	0.946
Flexibility	Collisions	0.944
Video games played/week	Collisions	0.942
Center line crossings	Low registration	0.941
Attention	Self-monitoring	0.934
Interest in driving	Attention	0.930
Initiation	Collisions	0.929
Flexibility	Inhibitory control	-0.923
Confidence in driving	Self-monitoring	0.912
Video games played/week	Working memory	-0.908
Video games played/week	Inhibitory control	-0.900

Table 5: Between Group CEFI scores, measuring executive functions for each participant.

	Participant #1	Participant #2	Participant #3	Participant #4
Comprehensive Executive Function Inventory (CEFI) parent report measure				
Overall Score*	**Low Average** Percentile: 16	**Below Average** Percentile: 7	**Low Average** Percentile: 9	**Low Average** Percentile: 13
Attention*	Below average	Low average	Below average	Low average
Emotional Regulation	Average	Low average	Low average	Low average
Flexibility	Low average	Average	High average	Low average
Inhibitory Control	Average	Low average	**Well below average**	Average
Initiation	Low average	**Well below average**	Average	Below average
Organization	Low average	Below average	Below average	Average
Planning*	Low average	Low average	Low average	Below average
Self-Monitoring	Low average	Below average	Below average	Average
Working Memory*	Low average	Below average	**Well below average**	Below average

Appendix B

Research Participant's Bill of Rights

STANBRIDGE UNIVERSITY RESEARCH SUBJECT/PARTICIPANT'S

BILL OF RIGHTS

Every person who is asked to be in a research study has the following rights:

1. To be told what the study is about and what will be measured;
2. To be told what will happen in the study and whether any of the procedures, drugs or devices are different from what would be used in standard practice;
3. To be told about important risks, side effects, or discomforts of the things that will happen to her/him;
4. To be told if she/he can expect any benefit from participating and, if so, what the benefits might be;
5. To be told what other choices she/he has and how they may be better or worse than being in the study;
6. To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study;
7. To be told what sort of medical treatment is available if any complications arise;
8. To refuse to participate at all before or after the study is started without any adverse effects. If such a decision is made, it will not affect his/her rights to receive the care or privileges expected if s/he were not in the study.
9. To receive a copy of the signed and dated consent form;
10. To be free of pressure when considering whether s/he wishes to agree to be in the study

Independent Contact: If you are in some way dissatisfied with this research and how it is conducted, you may contact the Stanbridge University Vice President of Instruction, Dr. Christine Mallon at cmallon@stanbridge.edu or 949-794-9090, x 5112.

Appendix C

Institutional Consent Form

Research Site Approval Form

Master of Science in Occupational Therapy

Institution/Program: Stanbridge University, STISIM Driving Simulator located in building 2021, Lab 4

Investigator's Name and Title: Dr. Sheryl Ryan, Thesis Advisor working with MSOT students Kathlyn Decena, Angie Higa, Cristina Jones, and Ellery Lockwood

Phone Number of Principle Investigator: (626) 975-5788

Title of Research: Teens with ADHD: Correlating Driving Errors with Sensory Processing and Executive Functioning

Description of Research: The purpose of the correlational study is to examine and describe the relationship between executive functioning and sensory processing with driving errors committed on a driving simulator by novice teen drivers diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). Researchers hypothesize that impairments in executive functioning and sensory processing will correlate with a higher frequency of driving errors on the driving simulator. Researchers are aiming for 30+ participants between the ages of 15.0 and 18.11 years old, with a pre-existing diagnosis of ADHD. Each of our participants should be novice drivers, meaning they have only up to one year of driving experience. Visual acuity should be at least 20/40, with or without the use of contacts or glasses. The participants should have the ability to travel to Stanbridge University, located in Irvine, where the driving simulator is located. Data will be gathered through a standardized intake form created by the researchers, Comprehensive Executive Function Inventory (CEFI), Adolescent/Adult Sensory Profile, and STISIM Drive virtual driving simulator. Data analysis will be done through correlational analysis, looking at the relationship between executive functioning, sensory processing, and

ADHD. Factor analysis will be done to correlate specific subgroups and scores with the others.

Our findings will contribute to the knowledge of driving abilities by teens with ADHD and can lead to the use of driving simulators to properly assess and treat driving impairments for teens with ADHD. This will expand our knowledge base regarding this issue for occupational therapists and other healthcare practitioners use for assessment, intervention, and treatment outcomes for various driving-related rehabilitation needs.

Participant Recruitment: Researchers will contact and/or recruit participants at this location by word of mouth, contacts with personal connections, and flyers in community agencies that provide services to youth with ADHD. Potential participants will be instructed to email the researchers at drivingsimulator8A@my.stanbridge.edu to schedule a time to meet at Stanbridge and complete study activities.

This site has agreed upon the recruitment and data collection methods to be used in this study and will receive information on the outcomes of this study. This research will be completed by Dr. Sheryl Ryan, Kathlyn Decena, Angie Higa, Cristina Jones, and Ellery Lockwood.

The investigator has permission to conduct research at:

Facility Name: Stanbridge University

Staff Name: Dr. Kelly Hamilton

Position: Vice President of Instruction

Signature: Kelly Hamilton[EV]

Date: 8.27.19

Appendix D

Recruitment Flyer

Appendix E

STANBRIDGE UNIVERSITY RESEARCH CONSENT FORM (adults, parents)

Description: You are invited to give permission for your child to contribute to research that will contribute to the study of the relationship between executive functioning and sensory processing with Attention-Deficit/Hyperactivity Disorder (ADHD). This is not a driver's education course.

Time Involvement: Once you provide consent by signing this form, you and your child will complete the intake form, CEFI and AASP Questionnaire. Your child will then participate in five driving simulator scenarios; two practice situations and three that will be recorded. At the end of the five scenarios, your child can use the simulator for optional driving practice for 30 minutes. All of this will take place at Stanbridge University in Irvine, California.

Risks and Benefits: We do not expect any negative effects for your child, and the study will not cause them any harm. If they do experience anything that negatively impacts them, you can withdrawal participation at any time. Your child will be asked questions about their habits and preferences within their daily routines, as well as basic medical information and driving experience in the intake form. All of your child's responses will be kept confidential. Their name will not be used in connection with any data associated with them. We will store our notes and recording in a locked office on our university campus.

Payment: You will be given a $10 gift card for participating in the research study.

Participant Rights: If you have read and signed this form you are allowing your child to participate in this project. Participation is voluntary and you have the right to withdraw at any point without penalty. Your alternative is to not participate in this study. Even if you consent to your child's participation, he/she will still be allowed to refrain from answering questions, or to stop entirely at any time, for any reason. Your child's specific interview responses will be kept confidential. The results of this study may be presented at professional meetings or published in scientific journals.

Contact Information: If you have any questions about this research you may contact the Faculty Advisor: Dr. Sheryl Ryan; Master of Science in Occupational Therapy Faculty, (949) 794-9090 x 5156.

Independent Contact: If you are dissatisfied or unhappy with how this research is conducted, you may contact the Stanbridge University Vice President of Instruction, Dr. Kelly Hamilton at khamilton@stanbridge.edu, 949-794-9090 x5112.

Participant Name ________________________________

Date ___________________

Participant Signature (If 18 or over)

____

Parent/Guardian Name ___________________________

Date ____________________

Parent/Guardian Signature

____

Appendix F

Teen Assent Form

We are from Stanbridge University and we are asking you to be in a study that will help contribute to the study of the relationship between executive functioning and sensory processing with Attention-Deficit/Hyperactivity Disorder (ADHD) .

What we are asking you to do:
We would like to ask you a few questions about your driving experience. We will then describe the driving simulator and the safety rules you need to know. You will have five driving scenarios; two practice scenarios and three that will be recorded for data. Afterwards, you will be given the option to practice on the simulator for 30 minutes.

Do I have to be in this study?
You do not have to participate in this study. It is up to you. You can say no now or you can even change your mind later. No one will be upset with you if you decide not to be in this study.

Will being in this study hurt or help me in any way?
This study will not harm you and if you do experience anything that negatively impacts you, you can quit at any time. There are no direct benefits to you for participating in this study. It will hopefully help us learn more about ways we can help teen drivers with ADHD with driving training and assessment.

What will you do with information about me?
We will be very careful to keep your answers to any of our questions private. Before and after the study we will keep all information we collect from you locked up and password protected. Additionally, you will be given a unique number so your name will not be associated with any of your data.

Agreement:

By signing this form, I agree to be in the research study described above.

Name: ____

Signature:____**Date:** ______________

Appendix G

Standardized Intake Form- Parent Section

Date: ________________

Date of Birth (teen):___________________ Gender: M F Not listed:

Please list any pre-existing medical diagnoses or conditions:
____
____

Please list any medications your teen takes:
____
____
____
____
____

Taken today? Yes No Taken today? Yes No Taken today? Yes No Taken today? Yes No Taken today? Yes No

Has your child experienced a seizure in the past year? Yes No

Does your teen wear glasses or contacts? Yes, glasses Yes, contacts No
If so, are they wearing them today? Yes No

Does your teen have a driver's license? Yes No
If no, does your teen have a driver's permit? Yes No
If no, has your teen completed online or classroom driver's education? Yes No
If no, has your teen started online or classroom driver's education? Yes No

STANBRIDGE UNIVERSITY

Appendix H

Teen Driving Form

When did you first start driving?

____

How often do you drive?

____

In what conditions do you normally drive? (e.g., daytime, night, highway, etc.)

____

Please rate your interest in driving.

0	**1**	**2**	**3**	**4**	**5**
Hate it			Sometimes		Love it

Please rate how confident you feel when driving.

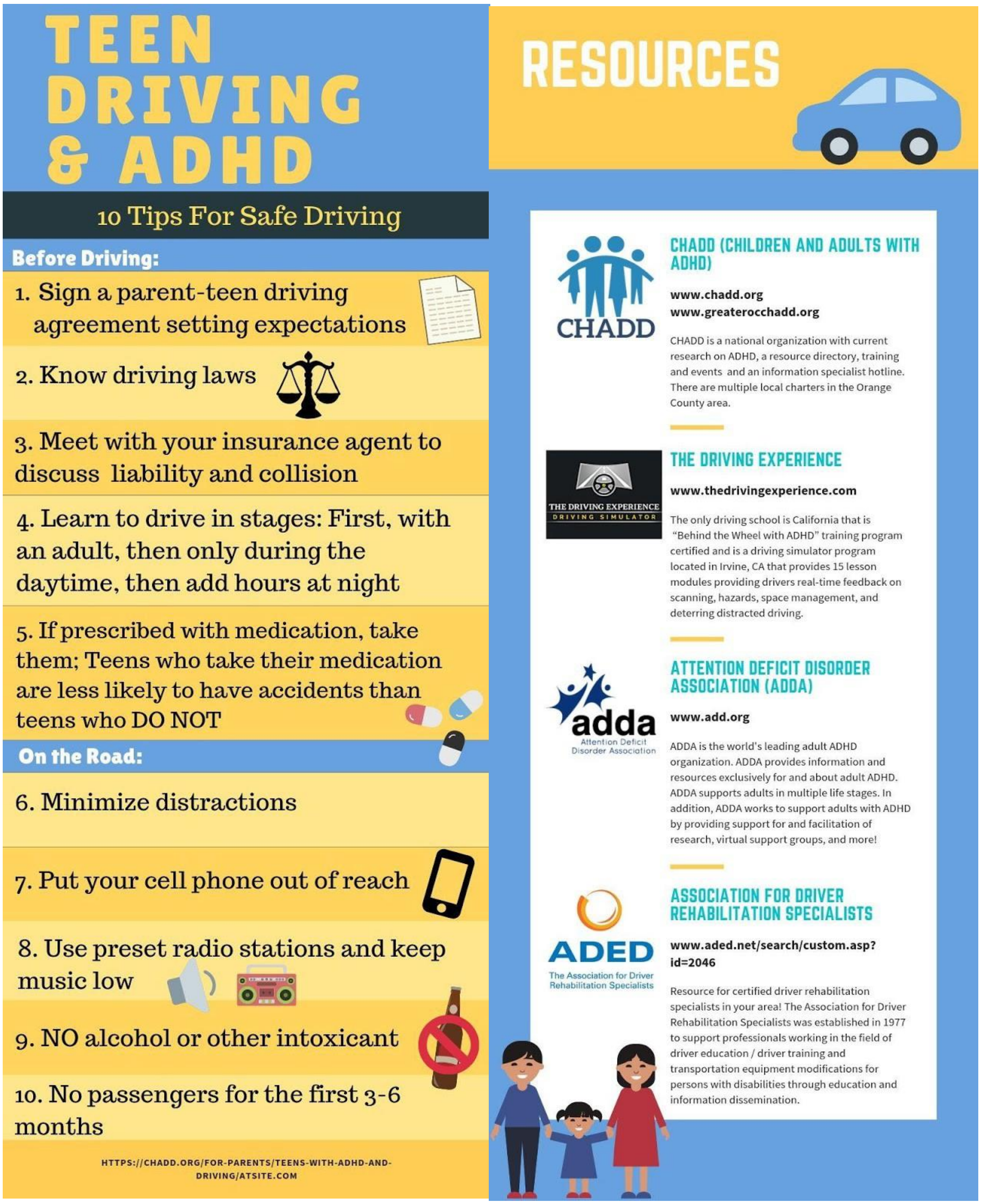
0	**1**	**2**	**3**	**4**	**5**
Not confident at all					Very confident

Do you play video games? Yes No

If so, how many hours do you play a week:_____________hours

Appendix I

Fact Sheet on ADHD and Driving



Appendix J

Simulator Statement

It is important to understand the simulator is not a substitute for on-road driving instruction. Proper assessment and training must be conducted through a verified Driver Education and Driver Training program accredited through the State of California Department of Motor Vehicles (DMV).

Use of the driving simulator during this research study does not meet any driver's educational requirements related to obtaining a driver's license through the state. The practice participants receive is free and supplemental to their legal DMV Driver Education and Training requirements.

For more information regarding driver education and resources in California, visit www.dmv.ca.gov/portal/dmv.

STANBRIDGE UNIVERSITY

Appendix K

Human Subject Incident Report Form

INCIDENT REPORT

Student Name:____________________ **Date:** ____________

Nature of Incident: ____

Witness(es):____

Incident Narrative: ____

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All incidents of injury or other adverse effects experienced by human participants must be reported to the IRBPHS: Stanbridge University Vice President of Instruction, Dr. Kelly Hamilton, khamilton@stanbridge.edu.

Utilize the Stanbridge University Incident report forms and protocol as indicated Stanbridge University Vice President of Instruction.

Appendix L

Confirmation of Application Receipt

STANBRIDGE UNIVERSITY CONFIRMATION OF RECEIPT OF COMPLETE IRBPHS APPLICATION

Date Approved: August 19, 2019

Dear: Dr. Ryan

Your application titled: *Teens with ADHD: Correlating Driving Errors with Sensory Processing and Executive Functioning* to the Institutional Review Board for the Protection of Human Subjects has been given the following file number: 01930.

Please allow 1-2 weeks from receipt of this notice for review.

Once you have submitted your application, you may not access your documents to make any changes or modifications until it is returned to you by the IRB team. You will be contacted by email if additional materials and/or clarifications are needed.

Questions should be directed to IRBPHS office by email (IRB@stanbridge.edu).