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Distracted Driving in Teens with and without Attention-Deficit/Hyperactivity Disorder

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Abstract

Objective—This study is among the first to examine the effect of talking on a cell phone or text messaging while driving in teens with and without Attention Deficit/Hyperactivity Disorder (ADHD).

Method—Teens (average age 17 years) with a diagnosis of ADHD (N=16) were matched with typically developing controls (N=18). All participants operated a driving simulator while (1) conversing on a cell phone, (2) text messaging, and (3) with no distraction during a baseline condition. Six indicators of driving performance were recorded: (a) time to complete the drive; (b) lane deviations; (c) variability in lane position (i.e., Root Mean Square [RMS]); (d) reaction time; (e) motor vehicle collisions; and, (f) speed fluctuation.

Results—Significantly greater variation in lane position occurred in the texting task compared to no task and the cell phone task. While texting, in particular, teens with ADHD took significantly less time to complete the scenario. No significant main effects of group were found.

Conclusions—Generally, those with ADHD did not differ in regard to driving performance, when compared to controls, with the exception of one outcome: time to complete scenario. These findings suggest that distracted driving impairs driving performance of teen drivers, regardless of ADHD status. Texting while driving had the greatest negative impact on driving performance, particularly with regard to variability in lane position (i.e., RMS). This study sheds light on key issues regarding injury prevention, with the intent of providing pediatric care providers with the

knowledge to inform teen drivers of risks associated with distracted driving which will ultimately result in reduced rates of motor vehicle crashes and concomitant injuries.

Introduction

1.0 Teen Motor Vehicle Collisions

The purpose of this study was to examine the impact of distracted driving, one of the leading contributors to motor vehicle collisions (MVCs), on driving performance of teens with and without Attention Deficit/Hyperactivity Disorder (ADHD). Motor vehicle collisions (MVCs) are the leading cause of mortality among teenagers, accounting for approximately one in three deaths among persons between the ages of 16 and 19 (Centers for Disease Control and Prevention [CDC], 2012). A variety of factors increase MVC risk for teen drivers: (1) they may be less able to anticipate and identify hazards than older, more experienced drivers; (2) they may be more willing to engage in risky behaviors than older, more experienced drivers (Lee, McElheny, & Gibbons, 2007); (3) they may lack the skill and judgment required to drive effectively and safely through dangerous environments (e.g., driving in the rain or in high traffic areas) (McGwin & Brown, 1999); and (4) given their proneness to impulsive behavior, they may be particularly vulnerable to distraction (Williams, 2003). Understanding the complexities of distraction is particularly important because distracted driving has been implicated as the cause of at least one in every five MVCs in which at least one person was injured or killed (CDC, 2014).

1.1 Distraction as a Risk Factor

Poor behavioral control known to exist among teens allows for distractions to become much more dangerous for them than for any other age group of drivers (Williams, 2003). While dangerous for any driver, distractions are significantly more detrimental to teen drivers because the task of driving demands more of their cognitive resources (Goodwin, Foss, Harrell, & O'Brien, 2012). Distracted driving occurs whenever a driver's attention is diverted from the primary driving task to an object, person, task, or event not related to driving (Olsen, Shults, & Eaton, 2013). Although distractions can encompass many different activities (e.g. eating, drinking, reading, reaching for items in the car), use of a cell phone (whether interacting, dialing, answering) is the most commonly studied and, according to some researchers, possibly the most dangerous form of distracted driving (Goodwin et al., 2012). This is due, in part, to the fact that cell phone use has become increasingly more common over the past few decades, and more and more people are interacting with devices while driving (CDC, 2014).

Additionally, it is well established in the literature that cell phone use compromises the performance of young drivers (Caird, Willness, Steel, & Scialfa, 2008; Drews, Pasupathi, & Strayer, 2008; Horrey, Wickens, & Consalus, 2006; Reimer, Mehler, D'Ambrosio, & Fried, 2010). However, a limited number of studies have examined cell phone distraction in novice, teen drivers (Klauer et al., 2011; Shinar, Tractinsky, & Compton, 2005). Neyens and Boyle (2008) concluded cell phone distraction may greatly increase the risk and severity of MVC-related injury and death for novice, teen drivers because of their relative inexperience and diminished attentional capacities.

1.3 Attention-Deficit/Hyperactivity Disorder

The increase in the likelihood of risky driving behavior and difficulties in attention regulation makes drivers with ADHD possibly even more susceptible to driving distractions (Reimer, Mehler, D'Ambrosio, & Fried, 2010). Teens with ADHD represent a particularly vulnerable driver population whose disabilities may only exacerbate the already cognitively demanding task of learning to drive and then doing so safely (Barkley & Cox, 2007; Jerome, Habinski, & Segal, 2006; Jerome, Segal, & Habinski, 2006; Reimer et al., 2010). ADHD is a neurodevelopmental behavior disorder affecting an 8.5% of the population (Froehlich et al., 2007), with males overrepresented at a ratio of three to one (Barkley, 2005). Teenagers with the Combined Type of ADHD (ADHD-C) are characterized as having impulsive, hyperactive, and inattentive behavior patterns (*Diagnostic and Statistical Manual of Mental Disorders– Fourth edition [DSM-IV]*, 1994), as well as deficits in executive functioning (Barkley, 2005). Studies have shown that teens with ADHD-C are more likely to engage in risky driving, but few studies have experimentally examined the potential increased risk that cell phone conversations or text messaging may introduce for typically developing, novice, teen drivers and their same age counterparts who have been diagnosed with ADHD-C (Barkley, Guevremont, Anastopolous, DuPaul, & Shelton, 1993; Barkley, Murphy, DuPaul, & Bush, 2002; Laberge, Ward, Manser, Karatekin, & Yonas, 2005).

Reimer et al. (2010) conducted one of the first driving simulator studies to investigate the effects of distracted driving on young drivers, ages 17 to 24, with and without ADHD. Participants were asked to navigate a high-stimulus, urban roadway while completing a phone task then, to navigate a low-stimulus, highway while completing a secondary task. During the highway scenario, drivers with ADHD had significantly more speed fluctuation and speed limit exceedances for longer distances compared to controls, suggesting that driving impairments associated with ADHD are most prevalent in non-demanding driving scenarios, such as low-stimuli highways. Although the study incorporated talking on a cell phone conversation as a distraction task, Reimer et al. (2010) did not examine the effects of text messaging, a dangerous activity that has since arisen as a prominent topic of societal importance since previous efforts. Because drivers with ADHD are one of the most “at risk” driver groups, and because teenagers are the most likely of all age groups to text while driving (CDC, 2014), it is very important to have an accurate understanding of the effects of text messaging on this exceedingly vulnerable population.

In addition to having a no -distraction and a cell phone conversation condition, Narad et al. (2013) introduced text messaging as a distraction task in their comparison of ADHD and typically developing controls’ simulated driving. Also, during the three distraction conditions, teens were presented with a single ‘unexpected event’ such as a car unexpectedly merging or a pedestrian crossing the street. Results were consistent with adult studies of ADHD drivers (see Vaa, 2014 for a review) in that regardless of whether ADHD teens were distracted or not, teens with ADHD exhibited greater variability in their lane position and speed than teens without ADHD. As expected, texting while driving also negatively impacted several indices of driving performance (i.e., speed, speed variability and variability in maintaining lateral lane position) for both ADHD and non-ADHD drivers (Narad et al., 2013). However, there were no significant group differences (ADHD vs. Control) or task

differences (no distraction vs. cell phone conversation vs. text messaging), even with regard to number of crashes. Further, no significant group or task differences were found when looking specifically at response to ‘unexpected events,’ likely because the ‘unexpected event’ only occurred once per distraction condition. Narad et al. (2013) speculated that the nonsignificant findings may have been due to the lack of ‘unexpected events,’ in the simulation particularly since there was only one unexpected and potentially hazardous event introduced to participants per secondary task. The present investigation increased statistical power to provide insight into how drivers with ADHD-C respond to hazards in the road environment by embedding more ‘unexpected events’ into driving scenarios, thereby providing a more accurate understanding of the effects of group and secondary task on driving performance.

1.4 Purpose

The current study compared the driving performance of teenagers with clinically diagnosed ADHD-C and a control group without ADHD-C. Addressing potential limitations of previous work and to address a significant research problem (Narad et al., 2013; Reimer et al., 2010), participants from both groups operated a virtual driving simulator embedded with numerous potentially hazardous situations, or ‘unexpected events,’ while (a) talking on a cell phone, (b) text messaging, or (c) driving with no task. It was hypothesized that teens would exhibit poorer driving performance during the text messaging task, given that this task involves more visual manual components that may make it more demanding than a cell phone conversation, and we believed that the impact of distraction would be significantly greater among those with ADHD-C. This information could be used by pediatric care providers and other front-line health care workers who can impact prevention efforts for reducing motor vehicle crashes.

Method

2.0 Participants

Twenty-two participants between 16 and 18 years of age, each having a previous clinical diagnosis of ADHD-C, and twenty-one typically developing control participants were recruited, and sampled to be similar on gender, ethnicity, and months of driving experience since receiving a driving permit. Teenagers with ADHD-C were recruited through local behavioral assessment clinics and from the community. Controls were recruited from the community. The study was approved by the university’s Institutional Review Board and participants provided written informed consent. The study was conducted prior to the release of DSM-V, although the criteria for ADHD that changed with the newest version of the DSM (e.g., for individuals > 16 years of age, only five of nine inattentive and hyperactive/impulsive symptoms must be endorsed for diagnosis of ADHD-C) did not impact the criteria used to identify drivers with ADHD-C for the current study.

Inclusion criteria for all participants were: (1) regular use of a cell phone with text messaging capability; (2) a participant’s willingness to use their personal cell phone during each testing session; and (3) a valid driver’s license. Exclusion criteria for both groups included physical disabilities so severe that they precluded their ability to participate fully in

any aspect of the experimental protocol. Because certain co-morbidities such as learning disabilities, conduct disorder and anxiety disorder are common in persons with ADHD-C (Larson, Russ, Kahn, & Halfon, 2011; Michielsen et al., 2013), participants with co-morbidities were not excluded nor were those with ADHD-C who were taking physician-prescribed stimulant medications. Individuals who were taking prescribed medications other than stimulants that remain active in the body for up to two weeks were excluded due to their inability to forego taking medication on the day of the session.

Participants taking stimulant medications for ADHD were instructed to forego their typical ADHD medication dose during the 12 hours prior to their appointment. All participants reported that 24 hours had elapsed since their last dose, thus meeting the clinically acceptable washout period for all stimulant medications prescribed to participants (Trick & Toxopeus, 2013). The breakdown of prescribed medications across participants was as follows: Short acting amphetamines (n=8), long acting amphetamines (n=7), short acting methylphenidate (n=2), long acting methylphenidate (n=3), was not prescribed medication for ADHD (n=2).

2.1 Procedure

Experimental tasks were administered using standardized protocols through a team of trained research assistants. Each participant received instruction in the operation and use of the driving simulator during a calibration session prior to actual data collection. Participants drove a brief, standardized simulator scenario while undistracted until they achieved stable driving performance. This was required, by protocol, to ensure each participant could demonstrate a minimum standard of proficiency with basic driving tasks.

Participants then engaged in the experimental driving task consisting of three five mile driving scenarios with the following tasks presented in random order: (a) no distraction, during which participants anticipated receiving a text message or phone call but received neither; (b) a cell phone conversation, where participants received a cell phone call immediately upon beginning the scenario and subsequently engaged in a naturalistic phone conversation for the remainder of the scenario; or, (c) a text message interaction, where each participant received a text message immediately upon beginning the scenario and engaged in reading and responding to text messages for the remainder of the scenario. The use of talking on a cell phone as a secondary task was similar to previous work; however, unlike the Reimer et al. (2010) study, which required participants to complete a specific task (i.e., scheduling an appointment during the cell phone task), the present study's cell phone and text messaging tasks were semi-structured to mimic a typical conversation with unfamiliar individuals (in this case, research assistants whose responsibilities included maintaining a natural conversation flow with each participant and asking open ended questions). The tasks matched those used in previous research efforts using simulators and were balanced across conditions in terms of topic areas discussed (e.g., family, friends, academics/school, extracurricular activities) and expected level of detail and difficulty of responses (e.g., numeric – "how old are you?", one word – "what is your favorite color?", detailed, "tell me about your family" (Stavrinou, Byington, & Schwebel, 2009, 2011; Stavrinou et al., 2013). There were no instances of simulator sickness reported by participants in the study after the

simulator drives. Subsequently, each participant completed five brief paper-and-pencil questionnaires documenting basic demographic information, cell phone and text messaging use, and driving history/experience.

2.2 Measures

2.2.1 Driving Simulator—Study participants engaged in a computerized driving simulation task to measure performance under specified conditions of interest (STISIM Drive, Systems Technology Inc., Hawthorne, CA). The simulation was displayed on three, 20" LCD computer monitors, providing a 135° field of view (Figure 1). The simulator provided a view of the roadway and dashboard instruments, including a speedometer, rpm gauge and a letter indicating the vehicle's gear. The vehicle was controlled by moving a steering wheel in a typical driving manner and depressing the accelerator and brake pedals accordingly. An on-board stereo sound system provided naturalistic engine sounds, external road noise, and sounds of passing traffic.

2.2.2 Driving Scenarios—Participants engaged in a brief five mile calibration drive with no secondary task introduced and were assessed for stable driving performance (e.g., ability to maintain a particular speed). For only this calibration drive, a verbal warning was presented to the driver when their speed was seven miles per hour greater or less than the posted speed limit. Research assistants recorded and summed the number of verbal warnings drivers received to determine whether additional practice was needed (threshold was > four warnings constituted a "fail" and required another drive). None of the study participants required a second practice drive. Once the participant demonstrated stable driving performance in the calibration drive, they were presented with three driving scenarios. Each of the three driving scenarios featured a two-lane, bi-directional five mile long road, enhanced by day-time suburban scenery and surrounding simulated vehicles, unlike the Reimer et al. (2010) which used high stimulus, urban and low stimulus, highway settings. Speed limits varied between 35mph and 65mph segments within the scenario and the same speed zones appeared in all three scenarios. While the Narad et al. (2013) study featured only one unexpected event, our participants were required to navigate through a total of twelve unexpected events that required immediate response (e.g., a lead vehicle braked suddenly, a pedestrian darted into the street, a cyclist swerved into the participant's lane), which were consistent across each scenario. Additionally, a large red stop sign appeared on the screen several times requiring participants to respond by depressing the brake pedal as quickly as possible. All events appeared across all three scenarios but the order of presentation of these events within each scenario was randomized to reduce potential practice effects (i.e., limit the participants' ability to anticipate the presentation of hazards).

2.2.3 Outcome Variables—Six indicators of driving performance were electronically recorded by the simulator:

- a. time to complete was measured as the time it took to complete the driving scenario with a specified secondary task. Since the scenarios were only fixed by length, time to complete the scenario differed across participants due to differences in driving speed;

- b. lane deviations served as an indicator of the degree of adjustment the driver implemented to maintain a desired position within the lane. Greater within-lane deviation indicated poorer driving precision. This is an important measure because lane deviation has been shown to be a sensitive indicator of the impairing effects of many factors suspected to disturb driving performance (Shinar et al., 2005; Weafer, Camarillo, Fillmore, Milich, & Marczinski, 2008). Lane deviations were coded as the total number of times the right tire touched or crossed the right line or the left tire touched or crossed the left line of the simulated roadway;
- c. root mean square (RMS), or standard deviation of lane position is a standard measure of steering variability (McGehee, Lee, Rizzo, Dawson, & Bateman, 2004). RMS of lane position differs from lane deviations in that lane deviations are a rough measure of crossing over roadway lines, while RMS of lane position provides an indication of the variability of the typical path of the vehicle. RMS of lane position has been used in previous studies as a more sensitive measure of demand of secondary tasks on lane variability (Marcotte et al., 2003);
- d. Reaction time reflected the amount of time in seconds that elapsed from the time of the event trigger (e.g., a stop sign appearing) to an accelerator position equal to 0, indicating pedal release (Rakauskas, Gugerty, & Ward, 2004). Meta-analyses reveal a consistent increase in reaction time during cell phone distraction (Caird et al., 2008);
- e. total number of simulated (virtual) motor vehicle collisions was calculated by summing the total number of times participants hit a person on the road (pedestrian or cyclist), hit another vehicle, and ran off the road across each driving scenario. Few studies have reported data on MVCs (Strayer & Drews, 2004);
- f. speed fluctuation was measured as the standard deviation of average driving speed. Speed fluctuation provides a fine grained measure of the difficulty a driver has in speed control, often observed when attention is divided (Stavrinos et al., 2013);

2.3 Data Analysis

A repeated measures analysis of variance (RM ANOVA) using a mixed model approach was used to determine the effect of experimental group (comparing those with and without ADHD-C) and secondary task (no task, cell phone, texting) on continuous driving performance outcomes (time to complete, RMS, reaction time, speed fluctuation). A generalized estimating equation (GEE) Poisson model was used for count-based performance outcomes (virtual collisions, lane deviations). These approaches allowed the analysis to account for factors that could affect driving ability (Fitzmaurice, Davidian, Verbeke, & Molenberghs, 2008). *P*-values less than 0.05 were considered significant for all analyses. All statistical analyses were conducted using SAS version 9.2.

Results

3.0 Participant Characteristics

Of the 43 participants who were recruited, nine were excluded due to missing driving performance outcomes resulting from a simulator technical error. The resulting sample of 34 participants (n ADHD = 16; n Control = 18) was used in all analyses.

The resulting sample of 34 participants averaged 17 years of age with approximately 15% represented by racial minorities (Table 1). The sample included more males than females, which was expected as more males have a diagnosis of ADHD-C (*Diagnostic and Statistical Manual of Mental Disorders– Fourth edition [DSM-IV]*, 1994). As expected, teens with ADHD-C exhibited significantly greater levels of childhood ADHD symptom severity than controls.

3.1 Primary Analyses

A significant main effect of task was found for variation in lane position (RMS). There was significantly higher RMS (i.e., greater variation) in the texting task compared to no task ($t(32) = 2.57, p = 0.0149$) and the cell phone task ($t(32) = 3.82, p = 0.0006$). There was a marginally significant main effect of task for two outcomes: lane deviations and reaction time. Post-hoc analyses revealed that participants had significantly more lane deviations in the texting task compared to no task ($\chi^2(1, N = 34) = 6.31, p = 0.0120$) and the cell phone task ($\chi^2(1, N = 34) = 11.77, p = 0.0006$). Post-hoc analyses also revealed that participants had a significantly increased reaction time to unexpected events in the texting task compared to the cell phone task ($t(30) = -2.52, p = 0.0172$) and a marginally significant increase compared to no task ($t(30) = 1.82, p = 0.0782$). A significant Task $\times$ Group interaction emerged for the time to complete scenario variable, indicating that while texting, in particular, teens with ADHD took significantly less time to complete the scenario (Figure 2). Table 2 includes all findings for each driving performance outcome. No significant main effects of group were found.

There were a total of 137 virtual collisions (28 person-related, 14 off road collisions, and 95 vehicle collisions) recorded across all participants. No significant differences were found between drivers with ADHD and controls in number of crashes or types of crashes: Drivers with ADHD accounted for 65 of the collisions (about 47%) and were dispersed as follows: (11 person-related, 6 off road, and 48 vehicle collisions). Controls accounted for 72 of the collisions (17 person-related, 8 off road collisions, and 47 vehicle collisions). In addition, there were no differences noted among tasks in number of crashes or crash types.

Discussion

4.0 Discussion of Findings

Though previous studies have demonstrated that individuals with ADHD exhibit impairments in their general driving performance (Barkley et al., 1993; Barkley et al., 2002) and in particular road environments such as highways or open roadways given the monotony of such environments (Reimer, D'Ambrosio, Coughlin, Fried, & Biederman, 2007), those

studies did not compare the impact of distraction across individuals with and without ADHD-C in their analyses. Contrary to our initial hypothesis regarding differences among groups, teens with ADHD did not have significantly poorer driving performance as compared to controls. Our findings are further supported by recent estimates indicating that the relative risk of traffic incidents among drivers with ADHD may be only slightly higher than their typically developing counterparts (Vaa, 2014). Driving performance was equally impaired by distraction in teen drivers both with and without ADHD-C, with the exception of one outcome: time to complete scenario. Findings suggested that drivers with ADHD-C took significantly less time to complete the scenario while texting; whereas, control participants displayed compensatory behavior (e.g., slowing of speed) during this task, mirroring findings of previous studies looking at similar behavior (Stavrinou et al., 2013). Reimer et al. (2010) found a similar pattern by measuring speed, such that drivers with ADHD displayed higher driving speed during times when they were distracted.

Overall, text messaging significantly impacted driving performance the most as evidenced by the significant increase in variability of lane position (RMS) and marginally significant increase in lane deviations and reaction time during this particular task. A texting interaction may place significant demands on a person's visual, manual, and cognitive resources. Driving is also largely a visual-spatial task. Given the limited capability for individuals to process information while performing two tasks that tap the same resource (i.e., both texting and driving are largely visual tasks) as outlined by the Multiple Resources Theory, it is easily understood how texting and driving may lead to degraded performance to the greatest degree (Wickens, 1984). Further, outcome measures may have been significantly influenced by the amount of time required to take one's eyes off of the road to read, compose, and send a text message. This is consistent with an earlier simulator study which reported that time spent with eyes off of the road increased by 400% when engaging in text messaging while driving compared to a non-distracted driving condition (Hosking, Young, & Regan, 2006).

Text messaging did not worsen driving performance on all six outcome measures. Despite not reaching statistical significance, participants experienced more virtual collisions during the text messaging task compared to driving while not distracted. It is possible that there was insufficient statistical power to detect significant differences on this driving indicator. Similarly, Narad et al. (2013) failed to find ADHD-related deficits for number of simulated motor vehicle collisions.

With regard to the findings pertaining to the impact of cell phone conversations as a distraction, the present study's findings are consistent with the only two previous studies assessing the impact of cell phone conversation as a distraction in ADHD (Narad et al., 2013; Reimer et al., 2010). Specifically, when distracted by cell phone conversations, young, inexperienced drivers with ADHD did not exhibit significantly more decrements in driving performance when compared to their non-ADHD controls. Despite differences in the ways participants were instructed to respond in cell phone tasks Reimer et al. (2010) employed a specific task that required participants to schedule an appointment while Narad et al. (2013) and the present study initiated conversational type tasks, findings suggest that consistency between experimental manipulations of cognitive tasks may evoke similar driving performance.

The findings indicate that distracted driving, whether in the form of a cell phone conversation or text messaging, negatively impacts driving performance. The present study underscores that distracted driving is impairing to teen drivers in general, not only those with attentional difficulties. Prevention efforts should include education of parents and teens through pediatrician offices or at a school nurse-level to help improve the traffic safety. Also, pediatric trauma and emergency care providers have the opportunity to make a community-level difference by discussing with adolescents how distracted driving incidents are entirely preventable and could describe real-world examples to illustrate the fatal consequences. Further, it is noteworthy that none of the participants in the current study were observed to pull off the side of the road to answer a call or respond to a text message. Health care providers could describe safe strategies such as this to drivers who might feel compelled to immediately respond to calls or texts.

4.1 Strengths and Limitations

First, we examined the driving performance of thirty-four teenagers, a modest sample size especially given that half the participants were further subdivided by ADHD diagnosis. A post hoc power analysis revealed that on the basis of the mean, between-groups comparison small effect size observed in the present study ($d = .17$), a total sample size of approximately 74 would be needed to obtain statistical power at the .90 level. Thus, a study examining a larger study population must be conducted if the results can be reliably generalized.

Second, we used a virtual driving simulator that provided for extensive data collection in a safe environment. Simulators have been validated as an acceptable measure of driving performance in research (Mayhew et al., 2011). We chose to use a driving simulator because it provided us with an inexpensive means with great experimental control to conduct this pilot study. The experimental control was essential in lending strength to our study in that each participant experienced the same driving conditions regarding speed limits, unexpected events, etc. so as to reduce noise that can contribute to influencing driving performance in the real world. The high number of unexpected events presented to participants in a simulated environment may have had unexpected influences on driving behavior in the following ways: 1) simulated crashes may have had some residual effect to participant behavior and 2) the increased risk of crashing in the simulator may have altered how drivers allocated attention between driving and secondary tasks. Future research may consider the distribution of crashes or near-crashes in driving simulator scenarios and how they impact subsequent participant behavior. Crashes are rare events in real-world driving and results with regard to crashes herein should be interpreted cautiously. However, it is important that crash data continue to be reported in future studies as research attempts to establish whether virtual crashes are a valid surrogate for real-world safety considerations.

Even the most technically sophisticated simulator is incapable of completely reproducing 'the real world' driving experience, so the generalizability of these results may be limited. For example, the frequent presentation of 'unexpected' events may have altered the drivers' attention resulting in an inadvertent hypervigilant state. This may have been particularly true for drivers with ADHD, whose attention may have never fully dropped away from the driving task as expected. In addition, the use of disproportionately large stop signs that were

dispersed throughout the scenario to capture reaction time data may have provided a less naturalistic warning to stop. Future studies may consider a naturalistic approach to document “real world” driving among individuals with ADHD. Also, there are several other identified sources of non-technology related distraction for drivers that were not tested in the current study, including passengers.

Conclusions

5.0 Conclusions and Future Impacts

Teen drivers cause many preventable MVCs. Distraction has been identified as one risk factor for MVCs, with the present findings indicating that text messaging significantly impacts teen driving performance, regardless of ADHD status. Additional studies are needed to understand the potential underlying mechanisms contributing to increased risk. Simulators could be used in the future as a possible training tool for teens to target improvement of driving performance in a safe and ethical manner. These findings also lay the groundwork for future naturalistic studies that may gain a better understanding of the impact of ADHD and various distractions (e.g., cell phones, music, peer passengers) on driving. This study sheds light on key issues regarding injury prevention with the intent of providing pediatric care providers with the knowledge to inform teen drivers of risks associated with distracted driving which will ultimately result in reduced rates of motor vehicle crashes and concomitant injuries for this at-risk group. Learning to drive safely is important for adolescents with ADHD as they transition to adulthood as it fosters their independence and community access/involvement. The current study also has research implications for other groups of youth with chronic physical conditions and behavioral issues for whom learning to drive is a realistic option, as it serves to support their goals for adulthood as well.

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Figure 1.
Photograph of the STISM driving simulator.

Figure 2.
Interaction of time to complete the scenario

Table 1

Demographic characteristics of sample by diagnostic group

Demographic Characteristic	ADHD-C		Control	
	Mean	SD	Mean	SD
Age (years)	17.25	0.99	17.09	0.89
Childhood ADHD Symptom Severity (total score)	26.00	15.90	12.67	5.94
Days Per Week Driven (number)	5.36	2.128	5.62	1.69
Time Since Permit (days)	606.73	330.98	665.38	347.57
	Frequency	Percent	Frequency	Percent
Gender				
Male	12	75.00	14	77.78
Female	4	25.00	4	22.22
Ethnicity				
Caucasian	14	87.50	15	83.33
Minority	2	12.50	3	16.67

Note. **Bold** indicates $p < 0.05$. ADHD symptoms are teen self-report of childhood behavior (ages 5–12).

Table 2

Main effect and interaction analyses of driving performance outcome variables.

	Mean $\pm$ SD					Main Effect of Task	Main Effect of Group	Task $\times$ Group Interaction
	No task	Cell phone	Text					
Time to complete	5.64 $\pm$ 0.78	5.56 $\pm$ 0.78	5.69 $\pm$ 0.97					
ADHD	5.81 $\pm$ 0.90	5.72 $\pm$ 1.02	5.47 $\pm$ 0.98		$F(2, 32) = 0.44$	$F(1, 32) = 0.70$	$*F(2, 32) = 3.77$	
Control	5.49 $\pm$ 0.64	5.43 $\pm$ 0.49	5.89 $\pm$ 0.93					
Lane deviations	4.12 $\pm$ 2.75	4.12 $\pm$ 2.67	6.32 $\pm$ 6.84					
ADHD	4.56 $\pm$ 2.97	4.13 $\pm$ 2.42	6.19 $\pm$ 4.53		$^{\dagger}\chi^2(1, N = 34) = 5.54$	$\chi^2(1, N = 34) = 0.03$	$\chi^2(1, N = 34) = 0.88$	
Control	3.72 $\pm$ 2.56	4.11 $\pm$ 2.95	6.44 $\pm$ 8.53					
RMS	1.14 $\pm$ 0.23	1.10 $\pm$ 0.23	1.23 $\pm$ 0.28					
ADHD	1.22 $\pm$ 0.24	1.15 $\pm$ 0.23	1.27 $\pm$ 0.29		$*F(2, 32) = 7.50$	$^{\dagger}F(1, 32) = 3.22$	$F(2, 32) = 0.52$	
Control	1.07 $\pm$ 0.21	1.06 $\pm$ 0.23	1.18 $\pm$ 0.27					
Reaction time	0.96 $\pm$ 0.20	0.95 $\pm$ 0.20	0.99 $\pm$ 0.18					
ADHD	0.98 $\pm$ 0.16	0.95 $\pm$ 0.19	1.01 $\pm$ 0.18		$^{\dagger}F(2, 30) = 3.24$	$F(1, 30) = 0.57$	$F(2, 30) = 1.34$	
Control	0.94 $\pm$ 0.23	0.94 $\pm$ 0.20	0.96 $\pm$ 0.18					
Virtual Collisions	1.26 $\pm$ 1.21	1.41 $\pm$ 1.08	1.35 $\pm$ 1.04					
ADHD	1.25 $\pm$ 1.24	1.38 $\pm$ 0.89	1.44 $\pm$ 1.21		$\chi^2(1, N = 34) = 0.26$	$\chi^2(1, N = 34) = 0.01$	$\chi^2(1, N = 34) = 0.35$	
Control	1.28 $\pm$ 1.23	1.44 $\pm$ 1.25	1.28 $\pm$ 0.89					
Speed fluctuation	18.87 $\pm$ 4.50	19.50 $\pm$ 3.64	18.56 $\pm$ 3.96					
ADHD	20.32 $\pm$ 3.70	20.15 $\pm$ 4.08	19.14 $\pm$ 5.05		$F(2, 32) = 1.71$	$F(1, 32) = 1.96$	$F(2, 32) = 0.74$	
Control	17.58 $\pm$ 4.85	18.93 $\pm$ 3.20	18.05 $\pm$ 2.71					

Note.

$^{\dagger} p < 0.05$;

$* p < 0.01$