Domain 3
Project 1

Distracted Driving in Teens with and without ADHD

Abstract

Objective: To determine the effect cell phone conversation or text messaging has on motor vehicle collision-related injury risk in teens with or without Attention Deficit/Hyperactivity Disorder – Combined Type (ADHD-C) and whether a computerized cognitive intervention improves driving performance of these individuals.

Patients or Other Participants: Teens (average age 17 years) with a diagnosis of ADHD-C (N=22) were matched with typically developing controls (N=21). Participants randomly assigned to the intervention completed 9 hours of training on RoadTour™ over 6 weeks. Four indicators of driving performance were recorded by the simulator: (a) deviation of lane position; (b) reaction time; (c) average driving speed; (d) total number of motor vehicle collisions.

Results: The repeated measures analysis of variance revealed main effects for driving condition on (a) reaction time ($F = 4.23$, $p = 0.02$), (b) motor vehicle collisions ($F = 3.31$, $p = 0.04$), and (c) number of deviations ($F = 21.68$, $p < 0.001$). The repeated measures analysis of variance revealed significant intervention effects for (a) motor vehicle crashes and (b) lane deviations.

Conclusions: Distraction negatively impacts driving performance of novice teenager drivers, regardless of ADHD-C status. Preliminary evidence suggests that the RoadTour™ intervention may be an effective tool for improving driving performance of novice drivers.

What's Known on This Subject

Motor vehicle collisions are the leading cause of mortality among teenagers. Evidence suggests this risk is higher while engaging in cell phone conversations and text messaging because the cognitive, physical and visual demands of these tasks interfere with driving performance.

What This Study Adds

This study is among the first to experimentally examine the potential increased risk cell phone conversations or text messaging introduce for typically developing, teen drivers and their same age peers who have been diagnosed with Attention Deficit/Hyperactivity Disorder – Combined Type.

Introduction

Motor vehicle collisions (MVCs) are the leading cause of mortality among teenagers, accounting for approximately 1 in 3 deaths among persons between the ages of 16 and 19.[1] A number of factors increase MVC crash risk for novice drivers: (a) they may be particularly vulnerable to distraction given their poor behavioral control, (b) they may be less able to anticipate and identify hazards, (c) they may be more willing to take risks,[2] and, (d) they may lack the skill and judgment required to navigate effectively and safely.[3]

Cell phone conversations and text messaging impose certain cognitive, physical and visual demands that interfere with driving performance given the verbal, motor and attention processing required to successfully engage in either task while driving.[4] It is well established in the literature that cell phone use compromises the performance of young adult drivers,[5-8] but few studies have examined cell phone distraction in novice, teen drivers.[9] Given the cognitive, visual, and motor constraints required to drive and compose a text message simultaneously, the effect of text messaging on driving performance may be even more detrimental than the effect of engaging in a cell phone conversation. Though multitasking is demanding for all drivers, it may greatly increase the risk and severity of MVC-related injury for novice, teen drivers because of their relative inexperience.[10]

Another group shown to be at-risk for poor driving performance are those who have been diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). ADHD is a behavior disorder affecting an estimated 3% to 7% of the population, with males overrepresented at a ratio of 3 to 1.[11] Teenagers with the Combined Type of ADHD (ADHD-C) are characterized as having impulsive, hyperactive, and inattentive behavior patterns,[12] as well as deficits in executive functioning.[11] These cognitive and behavioral deficits may be implicated in the driving environment. 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 peers who have been diagnosed with ADHD-C.[13, 14]

The purpose of the study was to determine the effect(s) of engaging in a cell phone or text messaging conversation had on increased MVC-related injury risk in teens with (and without) ADHD-C. Specifically, this study compared the driving performance of teenagers with a diagnosis of ADHD-C and a matched control sample without ADHD-C operating a virtual driving simulator while (a) engaged in a cell phone conversation, (b) engaged in a text messaging exchange, or (c) undistracted (Specific Aim 1). We hypothesized teens would exhibit riskier driving behavior during the text messaging condition given that it may be more cognitively demanding than a cell phone conversation, and we believed that the impact of distraction would be significantly greater among those with ADHD-C. In addition, we compared the short-term changes in driving performance of teens with and without ADHD-C in a virtual driving simulator as a function of a cognitive training intervention (Specific Aim 2). We hypothesized that driving performance would significantly improve post-cognitive training intervention for both groups.

Patients and Methods

Participants

This prospective intervention study was conducted at the University of Alabama at Birmingham's Translational Research for Injury Prevention Laboratory® between June 2009 and September 2010. This study was approved by the University of Alabama at Birmingham's Institutional Review Board for the Protection of Human Subjects. Written Informed Consent (parents) and assent (minors) were obtained.

A total of twenty-two, 16- to 18-year-old teenagers with a previous diagnosis of ADHD-C and twenty-one typically developing controls matched on gender, ethnicity, and months of driving experience since receiving permit were recruited. Teenagers with ADHD-C were recruited through local behavioral assessment clinics and from the community. Controls were recruited from the community.

Inclusion criteria for the two groups included those who regularly used a cell phone with text messaging capability and who were willing to use their personal cell phone during each testing session. Participants were required to possess a valid driver's license and to have access to a home computer in which to engage in the cognitive intervention, if randomly assigned to do so. Exclusion criteria for both groups included physical disabilities that precluded their ability to participate fully in any aspect of the experimental protocol.

Because certain comorbidities are common in persons with ADHD-C, participants with comorbidities were not excluded. Those with ADHD-C who were taking physician-prescribed stimulant medications were not excluded. Instead, they were instructed to forego taking their typical medication dosage during the 12 hours prior to their appointment. This was done for a separate but related study the results of which are not reported herein. However, those 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.

Procedure

Tasks were administered to the experimental and control group participants by a team of trained student research assistants who used standardized protocols. Figure 1 depicts participant flow through the study.

[Figure 1]

Session One Activities: Pre-Intervention. Each participant received instruction in the operation and use of the virtual driving simulator during a calibration session prior to actual data collection. Participants drove a standardized scenario without the introduction of a distraction until they achieved stable driving performance to make certain they could demonstrate a minimum standard of proficiency with regard to basic driving tasks.

Participants then engaged in the driving task which consisted of three, five mile driving conditions presented in random order. The three conditions were: (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 exchange, wherein participants received a text message immediately upon beginning the scenario and engaged in reading and responding to text messages for the remainder of the scenario. Cell phone and text messaging conditions were structured to mimic a typical, initial conversation between two persons not previously introduced.

Following the first simulator driving session, all participants completed several brief paper-and-pencil questionnaires documenting basic demographic information, cell phone and text messaging use, and driving history/experience. Participants drove in a second simulator driving session after completing the questionnaires to evaluate the effect of medication for those with ADHD-C (results not reported herein). All participants drove twice during the first session to eliminate the possibility of additional practice bias for those with ADHD-C.   Subsequently, half the participants were randomly selected to receive a cognitive intervention computer program at the end of the session. Those assigned to the intervention received the computer software and instructions for its use. All participants received monetary compensation for participation.

Cognitive Intervention. Those randomly assigned to the intervention condition were asked to complete a minimum of 9 hours of training on the Posit Science™ subtest RoadTour™. RoadTour™ is training program that consists of 90 minutes of training over a 6 week time period. Compliance was verified and documented when the participant connected to the internet via a central server at Posit Science which logged each training bout.[15]

Session Two Activities: Post-Intervention. Procedures for this session were similar to those in session one (see Figure 1). Before dismissal, study participants were debriefed and received monetary compensation for their participation.

Measures

Driving Simulator. Participants engaged in a computerized driving simulation task to provide a measure of driving 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 2). Participants sat within the simulator's passenger compartment which provided a view of the roadway and dashboard instruments, including a speedometer. The vehicle was controlled by moving a steering wheel in a typical driving manner and depressing accelerator and brake pedals accordingly. An on-board stereo sound system provided naturalistic engine sounds, external road noise, and sounds of passing traffic.

[Figure 2]

The driving scenarios featured a two lane, bi-directional road and day-time suburban scenery. Participants were required to navigate through a number of potentially hazardous situations. Speed limits varied within the scenario but remained constant across conditions.

Four indicators of driving performance were electronically recorded by the simulator:

(a) Deviation of lane position

(b) Reaction time

(c) Average driving speed

(d) Total number of motor vehicle collisions

Cognitive Intervention: Speed-of-Processing Intervention (RoadTour™). RoadTour™ is the latest version of the Useful Field of View (UFOV) speed-of-processing intervention designed to improve the efficiency and accuracy of visual information processing and the ability to perform complex visual attention tasks.[16] Users are trained to improve the speed and accuracy with which they identify and locate visual information using a divided attention format.[16] RoadTour™ retains the tasks used in previous efficacy trials with older adults, [16-21] but modifies the delivery platform so that it can be easily self-administered. The UFOV intervention is associated with improvements in everyday functional abilities[17] and driving skills.[18]

Data Analysis

A repeated measures analysis of variance (RM ANOVA) using a mixed model approach estimated the association between distraction condition and driving behaviors. The mixed model approach allowed the analysis to account for factors that could affect driving ability. [22, 23]

A RM ANOVA regression model was used to estimate the effect of a cognitive training intervention on driving performance in a virtual driving simulator. For each measure of driving behavior, separate models were run for each of three distraction conditions. An interaction between intervention and ADHD was used to determine whether the effect of the intervention differed by whether the individual had ADHD. Contrasts were used to produce *p*-value estimates for the comparison of the driving performance variables pre- and post-intervention. *P*-values less than 0.05 were considered significant for all analyses. All analyses were conducted using SAS version 9.2.

Results

Teens averaged 17 years of age with approximately 14% of the sample 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. Teens with ADHD-C exhibited significantly greater levels of childhood ADHD symptom severity than controls.

[Table 1]

Specific Aim One

"To compare the driving performance of teenagers operating a virtual driving simulator while (a) engaged in a cell phone conversation, (b) engaged in a text messaging exchange, or (c) undistracted"

Adjusting for driving period and medication use, significant main effects of condition emerged for three of the four driving behaviors examined. There was a significant main effect of distraction condition on reaction time (F = 4.23, p = 0.02). Reaction time was significantly longer in the texting period when compared to the cell phone (β = .05, p = 0.02) and the no distraction period (β = .05, p = 0.01). There was no difference in reaction time between the cell phone and no distraction conditions (β =.00, p = 0.87).

[Figure 3]

A significant main effect of condition emerged for number of MVCs (F = 3.31, p = 0.04), with more occurring during the cell phone condition than during the no distraction period (β=0.2742, p = 0.01). While the number of crashes was higher for the texting period compared to the no distraction period, this difference was not significant (β=0.14, p=0.18) nor was the difference between the cell phone and text messaging conditions (β=0.13, p=0.22).

[Figure 4]

A significant effect of condition on the number of deviations was revealed (F = 21.68, $p < 0.001$). This effect was limited to the texting condition compared to the no distraction condition (β = 1.72, p < 0.001) and to the cell phone distraction condition (β = 1.72, p < 0.001).

[Figure 5]

While there was no difference in mean speed among the distraction conditions (F = 0.20, p = 0.82) compared to the no distraction condition, mean speed was lower for both the texting (β = -0.38, p =0.57) and cell phone use (β = -0.35, p = 0.60) conditions.

Specific Aim Two

"To compare short-term changes in driving performance of teens with and without ADHD-C in a virtual driving simulator as a function of a cognitive training intervention"

There was no significant effect of the intervention on the mean number of lane deviations for the cell phone and no distraction driving periods; however, during the texting condition the mean number of lane deviations significantly declined post-intervention for individuals without ADHD (6.52 vs. 2.17, p<0.001) (Table 2). This effect was not present among those with ADHD

(6.91 vs. 5.87, p=0.65). The difference in the effect of the intervention was moderately significant by diagnosis of ADHD (p=0.05).

For the number of MVCs, there was no effect of the intervention during the cell phone distraction period. For the no distraction period, a significant reduction in the number of MVCs was observed among those without ADHD (0.89 vs. 0.18, p=0.0205). During the text messaging distraction period, a significant reduction in MVCs was observed among those with ADHD (1.07 vs. 0.39, p=0.04). No difference in the effect of the intervention between those with and without ADHD was observed, and the number of crashes decreased post-intervention for each model. There was no effect of the cognitive intervention on average speed and reaction time during the driving simulation.

[Table 2]

Discussion

Findings from Specific Aim 1 suggest that distraction negatively impacts driving performance of novice teenage drivers, regardless of ADHD status. This is in contrast to our hypothesis that the negative impact of distraction would be greatest among teens with ADHD-C. Though previous studies have demonstrated that individuals with ADHD exhibit impairments in their general driving performance, [13, 14] these studies have not compared the impact of distraction across individuals with and without ADHD-C in their analyses. Our findings are consistent with the only study to assess the impact of cell phone conversation as a distraction across these two populations,[8] which found that when distracted by cell phone conversations, that under more challenging driving conditions young adults, ages 17 to 24, with ADHD did not exhibit significantly more detriments in driving than did the young adults without ADHD.

Text messaging did not globally worsen driving performance as indicated by our driving performance measures. Rather, text messaging caused driving performance to deteriorate on two of the four driving performance measures: reaction time and lane deviations. It is not surprising that text messaging would impact these driving performance measures as these are likely sensitive to the amount of time required to take one's eyes off of the road to read, compose, and send a text message. This proposition is consistent with an earlier simulator study which found 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.[24] Despite not reaching statistical significance, participants in our series experienced more collisions during the text messaging condition compared to a period of driving when they were not distracted, and inspection of the statistical means suggests that when distracted by either cell phone conversation or text messaging, individuals slowed their driving speed. Reduced driving speed has been interpreted by others as an indicator of impaired driving performance and reduced driver efficiency.[7, 25] It is likely there was insufficient statistical power to detect significant differences on these driving indicators. Despite this, our findings readily confirm that distracted driving, whether in the form of a cell phone conversation or text messaging, negatively impacts driving performance.

Findings from Specific Aim 2 provide preliminary evidence that a cognitive speed of processing intervention may be an effective tool for improving driving performance with novice drivers. The six-week RoadTour™[16] intervention improved driving performance of all participants in our study; however, the pattern of improvement differed across diagnostic groups. Specifically, the frequency of lane deviations in the texting condition and crashes in the non-distracted condition was reduced post-intervention in novice drivers without ADHD while the number of crashes exhibited by novice drivers with ADHD was reduced in the texting condition post-intervention. This finding is consistent with our hypothesis that the intervention would improve driving performance in both groups.

Every study has limitations, and this study is no exception. Our study examined the driving performance of only forty-three teenagers; a modest sample size especially given that half the participants were further divided by ADHD diagnosis. A virtual driving simulator was used in our study to allow extensive data collection in a safe environment, but no simulator can completely reproduce a real world driving situation. Finally, the self-administered cognitive speed-of-processing intervention includes certain game elements to stimulate the interest of potential users. However, given the advanced technologies to which teenagers are currently exposed in common video games, the training program may still prove ultimately disinteresting to younger study populations.

Conclusion

The present study not only underscores that distracted driving is impairing to all novice drivers, not just those with attention difficulties, but also provides empirical evidence of the positive impact of a cognitive speed-of-processing intervention on improving teen driving performance. A study examining a larger sample size must be conducted if the results can be reliably generalized to the US teen population. Future studies might consider a naturalistic approach so as to observe teen driving during a routine day, as well as the impact of UFOV training, under actual roadway conditions.

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Figures

Figure 1. Participant Flow Through Study

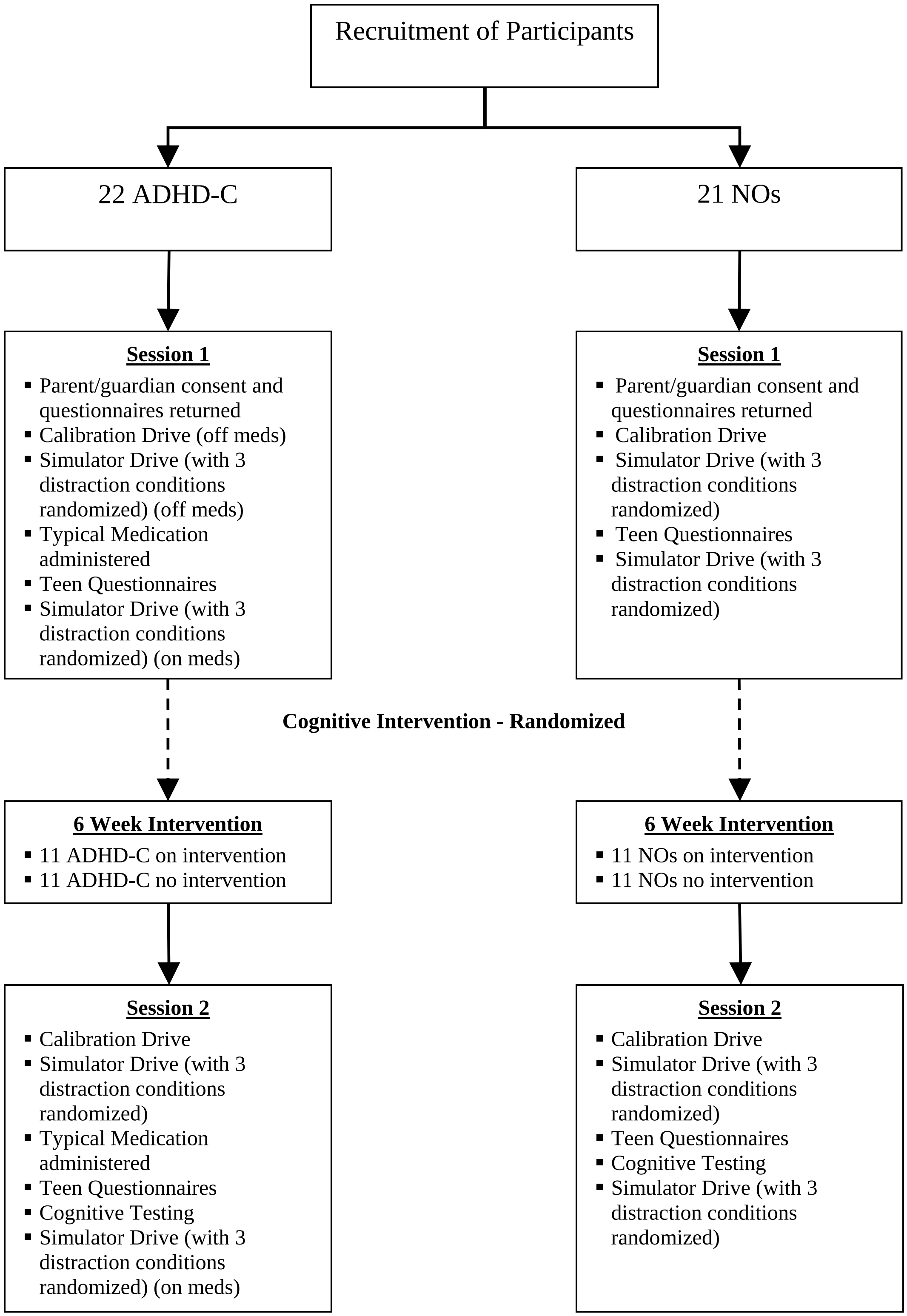
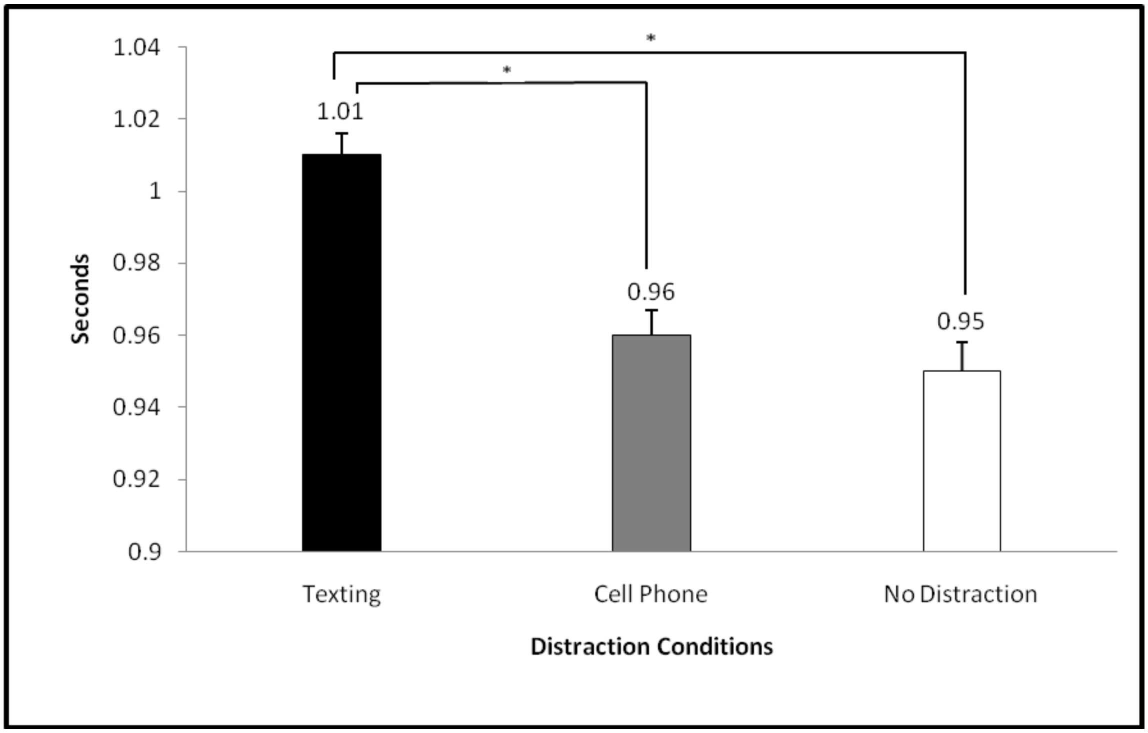


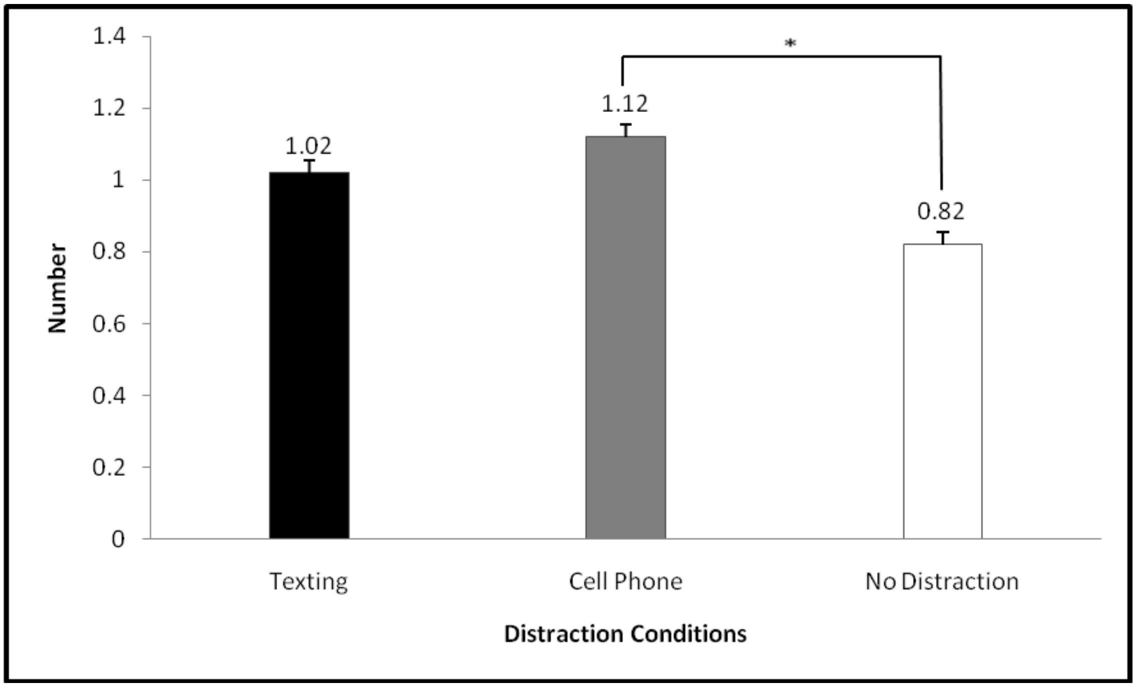
Figure 2. STISIM Driving Simulator

Figure 3. Average Reaction Times Across Distraction Conditions



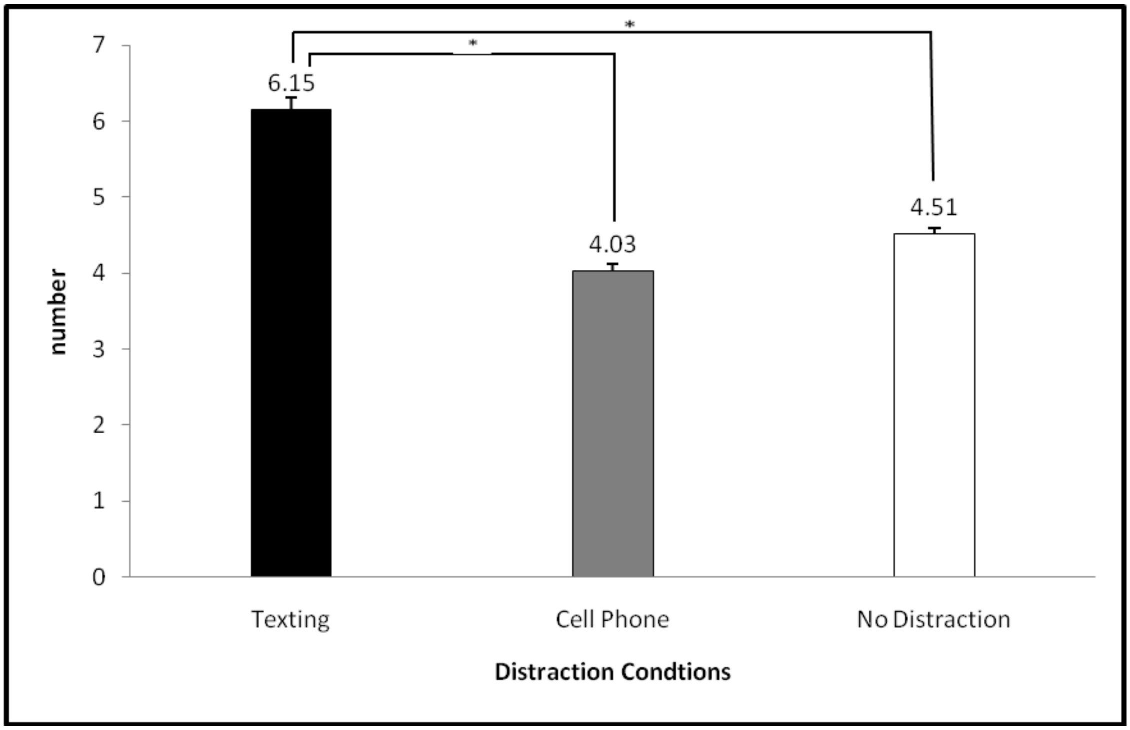
*$p < 0.05$

Figure 4. Average MVCs Across Distraction Conditions



**p* < 0.05*

Figure 5. Average Lane Deviations Across Distraction Conditions



**p < 0.05*

Tables

Table 1. Demographic Characteristics of Sample by Diagnostic Group

	ADHD-C		Control	
Demographic Characteristic	Mean	SD	Mean	SD
Age (years)	17.07	0.92	17.16	0.94
Childhood ADHD Symptom Severity (total score)	**26.23**	**14.61**	**14.62**	**7.55**
	Frequency	Percent	Frequency	Percent
Gender				
Male	16	72.7	15	76.2
Female	6	23.7	6	23.80
Ethnicity				
Caucasian	19	86.4	18	85.7
Minority	3	13.6	3	14.3

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

Table 2. The effect of a cognitive training intervention on driving performance in a virtual driving simulator by diagnosis of ADHD-C and type of distraction

	No distraction				Texting				Cell-phone			
	Pre	Post	p-value*	p-value$_{int}$*†	Pre	Post	p-value*	p-value$_{int}$*†	Pre	Post	p-value*	p-value$_{int}$*†
Speed												
ADHD+	29.97	29.75	0.14	0.44	30.65	30.20	0.95	0.27	30.32	31.00	0.67	0.88
ADHD-	32.56	34.31	0.35		30.86	33.59	0.20		31.38	32.37	0.50	
Deviations												
ADHD+	5.24	5.48	0.10	0.72	6.91	5.87	0.65	0.05	4.16	5.28	0.14	0.25
ADHD-	3.70	3.58	0.87		6.52	2.17	< 0.001		3.67	3.68	0.99	
Reaction time												
ADHD+	0.97	0.97	0.64	0.87	1.01	1.01	0.91	0.82	0.95	0.95	0.99	0.92
ADHD-	0.91	0.91	0.89		0.99	0.98	0.77		0.95	0.94	0.90	
Crashes												
ADHD+	1.02	0.36	0.07	0.90	1.07	0.39	0.04	0.70	1.20	0.72	0.19	0.57
ADHD-	0.89	0.18	0.02		1.06	0.54	0.08		1.09	0.84	0.37	

* Estimated from repeated measures ANOVA
† p-value for interaction between ADHD and intervention