Original Investigation

Impact of Distraction on the Driving Performance of Adolescents With and Without Attention-Deficit/Hyperactivity Disorder

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IMPORTANCE This study extends the literature regarding attention-deficit/hyperactivity disorder (ADHD)–related driving impairments to a newly licensed, adolescent population.

OBJECTIVE To investigate the combined risks of adolescence, ADHD, and distracted driving (cell phone conversation and text messaging) on driving performance.

DESIGN, SETTING, AND PARTICIPANTS Adolescents aged 16 to 17 years with (n = 28) and without (n = 33) ADHD engaged in a simulated drive under 3 conditions (no distraction, cell phone conversation, and texting). During each condition, one unexpected event (eg, another car suddenly merging into driver's lane) was introduced.

INTERVENTIONS Cell phone conversation, texting, and no distraction while driving.

MAIN OUTCOMES AND MEASURES Self-report of driving history, average speed, standard deviation of speed, standard deviation of lateral position, and braking reaction time during driving simulation.

RESULTS Adolescents with ADHD reported fewer months of driving experience and a higher proportion of driving violations than control subjects. After controlling for months of driving history, adolescents with ADHD demonstrated more variability in speed and lane position than control subjects. There were no group differences for braking reaction time. Furthermore, texting negatively impacted the driving performance of all participants as evidenced by increased variability in speed and lane position.

CONCLUSIONS To our knowledge, this study is one of the first to investigate distracted driving in adolescents with ADHD and adds to a growing body of literature documenting that individuals with ADHD are at increased risk for negative driving outcomes. Furthermore, texting significantly impairs the driving performance of all adolescents and increases existing driving-related impairment in adolescents with ADHD, highlighting the need for education and enforcement of regulations against texting for this age group.

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Motor vehicle crashes (MVCs) result in an estimated 32 788 deaths[1] and 2.8 million injuries per year.[2] Adolescent drivers, especially newly licensed drivers,[3-5] contribute disproportionately to rates of MVCs. In fact, adolescents are 4 times more likely to be involved in a MVC than drivers older than 20 years of age.[6]

Distracted driving, behavior performed while driving that involves taking one's eyes of the road (visual), hands off of the wheel (manual), or mind off driving (cognitive), is one of the primary causes of most MVCs.[3,7,8] Although many contextual factors contribute to distracted driving, cell phone–related distracted driving fatalities are an ever-increasing phenomenon and account for an estimated 18% of all distracted driving-related deaths.[1] Currently, 77% of drivers engage in cell phone conversation,[9] 81% of young adults write text messages, and 92% of young drivers read text messages while driving.[10] While several studies have suggested that driving performance is impaired when individuals are distracted by cell phone conversation,[11,12] the detrimental effects of texting on driving performance[13-15] is relatively understudied. Furthermore, to our knowledge, no studies have examined the effects of texting on the driving performance of adolescent drivers, despite the fact that adolescents are the most frequent users of text messaging[16] and comprise the largest percentage of individuals involved in phone-related fatal MVCs.[17]

While adolescents as a group are at increased risk for distracted driving and MVCs, those diagnosed as having attention-deficit/hyperactivity disorder (ADHD) present an even greater risk. Individuals with ADHD have higher rates of MVCs and experience greater tactical and operational driving impairments than their non-ADHD counterparts.[18] Given documented ADHD-related deficits in divided attention,[19] combining driving with cell phone use is likely to impair the driving ability of adolescent drivers with ADHD more than typical novice drivers.

The present study examined the detrimental effects of cell phone conversation and texting on driving behavior in adolescents with ADHD and, to our knowledge, is among the first studies to address the combined risks of (1) adolescence, (2)ADHD, and (3) distracted driving. Similar to adult drivers,[20] we predicted that adolescents with ADHD would display poorer driving performance than those without ADHD. Additionally, we hypothesized that engagement in a cell phone conversation or texting would impair the performance of all adolescents, with the greatest impairment occurring during texting because texting involves all 3 forms of distracted driving (ie, visual, manual, and cognitive). Furthermore, we predicted that the decrement in driving performance observed when adolescents with ADHD engaged in cell phone use would be significantly greater than that observed in adolescents without ADHD.

Table 1. Demographic Characteristics of the Attention-Deficit/Hyperactivity Disorder and Control Groups

	Mean (SD)	
	Attention-Deficit/Hyperactivity Disorder (n = 28)	Control (n = 33)
Age, y	16.86 (0.59)	17.14 (0.59)
Male, %	60	63
Wechsler Abbreviated Scale of Intelligence full-scale IQ	106.9 (11.55)	104.7 (8.24)
Medication status (yes), %	75	0
Comorbidity (ODD), No. (%)	2 (7.1)	0 (0)
Months of driving experience	6.45 (5.91)	10.45 (7.84)

Abbreviation: ODD, oppositional defiant disorder.

Methods

Power analysis determined a sample size of 60 would have 80% power to detect a moderately sized between-group effect. Because the effects of texting on driving behavior are large,[13] our sample size of 60 had more than 99% power to detect a moderately sized within-group effect of our texting manipulation and also 99% power to detect a moderately sized group by distraction interaction.

Participants

A total of 61 adolescents (ADHD = 28, control = 33) aged 16 and 17 years with a valid driver's license participated in the study. Participants in the ADHD group met current *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) criteria for ADHD (ADHD–combined type, n = 3; ADHD–predominantly inattentive type, n = 25) as determined by the Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version.[21] Participants in the control group were required to have fewer than 3 total *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) symptoms of ADHD assessed using the Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version. All participants were required to have a full-scale IQ greater than 80 as measured by the Wechsler Abbreviated Scale of Intelligence. **Table 1** provides the demographic information. All study procedures where approved by a local institutional review board.

Driving Simulator

Participants completed a 40-minute drive on a STISIM Model 400 simulator equipped with a 42" high-definition video monitor displaying the roadway (Systems Technology Inc). The simulator is equipped with full-size steering and braking/acceleration controls. The roadway consisted of 2 lanes separated by a dashed yellow line and proceeded through urban and suburban settings. The drive consisted of sections of straight and curving roadways with other vehicles in the driver's lane, as well as the opposite lane of travel. Speed-limit signs were posted along the roadway.

Prior to the start of the drive, participants completed a 3-minute practice drive to orient them to the simulator controls. Then, participants were instructed to "drive as you normally would," and were told that during the drive, they would receive telephone calls and text messages to which they needed to respond. Participants practiced using a text-enabled cell phone equipped with a hands-free headset. The first 10 minutes of the experimental drive were an adjustment period during which participants familiarized themselves with the driving simulator. The remaining 30 minutes were divided into 3 separate 10-minute periods. During each period, participants were engaged in (1) cell phone conversation, (2) texting, or (3) no distraction. The order of the 3 conditions was counterbalanced across participants and each order of conditions occurred equally across groups. During the conversation and texting conditions, an experimenter seated in another room engaged the participant in a cell phone conversation or text message exchange. The texting condition consisted of a continuous exchange between participant and experimenter. The content of the conversation and texting interactions were guided using 2 lists of randomly selected questions from *The Book of Questions*.[22] Questions ranged from simple questions (ie, what is your favorite food?) to more complex situational questions (ie, if you found a wallet with $5000, what would you do?). The use of the 2 lists was counterbalanced across the conversation and texting conditions.

During the course of each of the 3 experimental conditions, one unexpected event occurred: a car suddenly merged into the driver's lane or a pedestrian suddenly crossed the street in front of the participant's vehicle.

Driving speed and lateral position were sampled every 30 milliseconds during the entire drive. The first 4000 feet (ie, approximately first minute) of each condition was systematically removed from analyses to control for carry-over effects across conditions. Also, because participants' responses to experimenter-initiated unexpected events (eg, braking and swerving) impact measures of speed and lateral position, the 1000 feet (ie, approximately 15 seconds) following the deployment of the unexpected event were also removed from analyses. The remaining data were summarized by calculating the mean and standard deviation (SD) of speed in miles per hour, and the SD of the lateral position in feet for each condition. In addition, braking reaction time (RT) in seconds was calculated by subtracting the time the unexpected event occurred from the time braking was initiated. Finally, if the participant's vehicle made contact with the deployed object, a crash was coded.

Procedure

During a screening visit, all participants and their parent(s) provided informed consent. Parents and adolescents completed the Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version. Adolescents completed the Wechsler Abbreviated Scale of Intelligence and a driving history questionnaire, which queried months of driving experience, previous crashes, citations, and risky driving behavior including experience engaging in cell phone use while driving. Eligible participants were scheduled for a separate driving simulator visit. One control participant reported motion sickness during the beginning of the drive and therefore was excluded. Participants taking stimulant medication refrained from taking medication the day of the simulator drive. We chose to test adolescents while not taking medication to accurately evaluate ADHD-related deficits.

Results

Adolescents with ADHD self-reported fewer months of driving experience (mean [SD], 6.45 [5.91]) than control subjects (mean [SD], 10.45 [7.84]) (t_{60} = 2.22; P = .03; Table 1). To control for this group difference, all subsequent analyses included months of driving experience as a covariate.

Driving History

Using logistic regression, we found that a larger proportion of adolescents with ADHD reported receiving at least 1 traffic violation (17%) compared with control subjects (6%; χ^2_1 = 4.73; P = .03). However, there was no difference between the proportion of participants with ADHD (28%) and control subjects (21%) who reported being involved in a crash (χ^2_1 = 1.78, P = .18). Groups did not differ on history of cell phone use while driving (ADHD = 64%, control = 72%; χ^2_1 = 0.21; P = .65).

Driving Simulator

A 2 (group: ADHD vs control) × 3 (condition: no distraction vs conversation vs texting) mixed-model multivariate analysis of covariance was conducted controlling for months of driving experience. Dependent variables included the 4 continuous driving simulator variables (average speed, SD speed, SD lateral position, and braking RT to the unexpected event). Significant main effects of group ($F_{4,55}$ = 3.42, P = .01) and condition ($F_{8,51}$ = 8.20, P = <.001) were evident. However, the interaction was nonsignificant ($F_{8,51}$ = 1.50, P = .18). Follow-up analyses of the group main effect demonstrated that adolescents with ADHD had more variability in their speed (d = 0.64) and lateral position (d = 0.90) than control subjects. There were no differences between groups for average speed or braking RT (**Table 2**). Follow-up analyses of the condition main effect showed that during texting, adolescents drove slower, evidenced more speed variability, and were more variable in their lateral position compared with their driving behavior during the no distraction (all P < .001; $d_{\text{mean speed}}$ = 0.66, $d_{\text{SD speed}}$ = .45, $d_{\text{SD lateral position}}$ = .71) and conversation (all P < .001; $d_{\text{mean speed}}$ = 0.57, $d_{\text{SD speed}}$ = .49, $d_{\text{SD lateral position}}$ = 1.31) conditions. Finally, adolescents had less variability in lateral position during the conversation condition compared with the no distraction condition (d = 0.63).

A 2 (group) × 3 (condition) mixed-model logistic regression was conducted to examine the response to the unexpected event (crash/no crash). There were no main effects of group (χ^2_1 = 0.15, P = .70), condition (χ^2_2 = 4.28, P = .12), or their interaction (χ^2_2 = 1.10, P = .58). Because participants may have learned from prior unexpected events, this analysis was also completed analyzing only the first event for each participant. The results remained nonsignificant (group: χ^2_1 = 1.19, P = .28; condition: χ^2_2 = 5.43, P = .07; interaction: χ^2_2 = 3.72, P = .16).

Discussion

The observed ADHD-related driving impairments are consistent with previous research in young adults demonstrating that

Table 2. Outcome Variables by Group and Condition and Univariate Results

	Mean (95% CI)						*F*		
	Attention-Deficit/Hyperactivity Disorder			Control					
Effect	No Distraction	Conversation	Text	No Distraction	Conversation	Text	Group	Condition	Interaction
Reaction time, s	1.92 (0.38)	2.27 (0.43)	2.21 (0.34)	2.17 (0.40)	2.10 (0.35)	2.12 (0.33)	0.05	0.242	0.81
Mean speed, MPH	57.07 (2.76)	56.78 (2.46)	51.61 (2.97)	55.63 (1.83)	54.57 (1.93)	52.50 (1.56)	0.45	11.58[a,b]	1.87
SD of speed, MPH	9.71 (1.08)	9.47 (1.23)	11.01 (1.13)	7.96 (1.11)	8.14 (0.66)	9.62 (1.22)	5.94[c]	10.30[b,d]	0.59
SD of lateral position, ft	1.48 (0.16)	1.24 (0.11)	1.85 (0.22)	1.17 (0.15)	0.95 (0.11)	1.51 (0.18)	11.76[e]	23.62[b,f]	0.08

Abbreviation: MPH, miles per hour.

[a] No distraction = conversation > text messaging.

[b] *P* < .001.

[c] *P* < .05.

[d] No distraction = conversation < text messaging.

[e] *P* < .01.

[f] Conversation < no distraction < text messaging.

adolescents with ADHD display greater variability in speed and lane position than participants without ADHD.[23-25] To our knowledge, this is the first simulator study that has focused exclusively on adolescents with ADHD, extending our knowledge of ADHD-related driving deficits to adolescents. Moreover, this study demonstrates that deficits are evident from the time adolescents with ADHD receive their driver's license. Driving deficits related to ADHD appear to impact specific driving behaviors, namely, variability in speed and lane position. Because both maintaining a consistent speed and central, consistent lane position require constant attention to the road and one's surroundings,[26] the pattern of our findings are not surprising.

There were no ADHD-related deficits for average speed, braking RT, or likelihood of a crash during the deployed event. The lack of differences on average speed suggests that ADHD-related deficits are localized to speed variability and not necessarily excessive speed. With regard to crashes, results across studies have been mixed.[23,24] One possible reason our study did not find group differences on crash events may have been the limited experimenter-initiated prompts to crash (1 per condition), which could have limited power to detect effects for this variable.

The effects of cell phone distraction were large and evident across multiple driving behaviors (ie, average speed, speed variability, and variability in lateral position). As predicted, texting was the most impairing distraction, adding to the limited literature showing texting to impair driving.[13,27,28] The need to divert one's visual gaze from the road while texting creates a visual distraction that impairs one's ability to maintain a constant speed and central lane position. While the texting-related impairments observed in this study (ie, increased variability in speed and lateral position) have minor ramifications in the simulator environment, these impairments can be fatal in the real-world driving environment.[16,17] To illustrate, we computed the percentage of time that participants spent outside of their lane while texting. During texting, adolescents with and without ADHD were outside of their lane for 3.30% and 2.03% of the drive, respectively, compared with 1.76% and 0.70% of the time, respectively, during the no distraction condition. Hence, texting doubles or triples the risk for leaving one's lane. Moreover, texting additively affects existing ADHD-related driving impairments, thus incrementally increasing driving risk for adolescents with ADHD.

Texting also affected driving behavior by slowing drivers down. It has been suggested that texting while driving strains cognitive load because of the cognitive, visual, and manual aspects of the task. As a result, individuals may compensate by reducing speed.[14,29] However, decreased speed is occurring in the context of increased variability in speed. While slower speeds may be beneficial in some driving situations, reductions in speed, particularly if occurring irregularly, can impact traffic congestion[30] and highway safety.[31-34]

In contrast to the highly detrimental effects of texting on driving, engagement in a cell phone conversation did not impair driving performance as expected. Other researchers have reported similar findings.[29,35] A possible reason for failing to detect a negative impact for cell phone conversation is failure to capture driving behavior while answering the cell phone. By removing the first minute of each condition to control for any carry-over effects from the previous condition, we did not capture the diversion of visual attention while answering the phone, which may be the most impairing component of a cell phone conversation. Also, while research studies have indicated that hands-free headsets pose the same risks as using a handheld cell phone while driving,[36] it may be that our use of a hands-free headset reduced the manual distraction of holding the phone.

Not only was cell phone conversation while driving not impairing, for at least 1 outcome (ie, SD lateral position), cell phone conversation improved driving performance.[35,37] These findings mirror the work of Atchley and Chan,[38] who reported a decrease in lateral position variability when engaged in a cell phone conversation during boring drives, suggesting that a concurrent cognitive task can improve performance during drives when vigilance is low. While the present drive was not designed to be monotonous, the simulator lacked other forms of stimulation (eg, radio). Thus, it is possible that the drive was in fact a monotonous task for the adolescents. Furthermore, research studies examining eye gaze while driving demonstrate that when individuals are engaged in a verbal task while driving, they are more likely to concentrate their gaze on the center of the roadway.[35,39,40] In addition, during routine driving, a secondary task may serve to increase the effort directed toward the task.[41] Although cell phone conversation may help centralize eye gaze and keep lane variability to a minimum, there may be costs associated with such a central focus including inattention blindness[42] and impaired ability to respond to peripheral events. While we did not find increased crashes to the deployed event during conversations, all events were deployed in the center of the individual's visual field. Had these events occurred more peripherally, the negative effects of conversing on a phone may have been evident.

No group by condition interaction was found for any driving outcome, suggesting that the decrement in performance created by texting was similar for individuals with and without ADHD. However, it is important to note that adolescents with ADHD have baseline driving impairments and texting incrementally impairs their driving. When the distraction of a cell phone was introduced, the performance of this group deteriorated incrementally and posed additional risks. As an illustration of this phenomenon, adolescents with ADHD increased the amount of time outside their lane from 1.76% during no distraction to 3.30% during texting. The impact of texting while driving on adolescents with ADHD translated into a 371% increase in the time they were outside their lane compared with control subjects during no distraction. Also of note, when adolescents without ADHD were texting, they spent as much time out of their lane (2.03%) as did drivers with ADHD when they were not distracted (1.76%), providing further evidence of the detrimental impact of texting for all drivers.

This study had several limitations. First, driving performance was examined in the context of a simulator. While it is an artificial driving environment that only captures a sampling of driving behavior, studies have cited the validity of simulator use, noting that it is a safe and controlled method for assessing high-risk driving behaviors.[43-45] Furthermore, the driving scenario only included suburban and urban driving roadways. The work of Reimer and colleagues[46] suggests that roadway factors may influence driving outcomes, and the effect of distracted driving may vary by environment. The impact of distraction on different roadway types (eg, highway settings) and conditions (eg, weather and traffic) should be examined in future studies to further understand the impact of distracted driving on adolescent drivers. Also, with regard to the sample, the ADHD group had little comorbidity, which may not be representative of many adolescents with ADHD. Some studies have suggested that certain comorbidities (eg, oppositional defiant disorder/conduct disorder) increase driving risk.[47] Additionally, our groups were not matched on months of driving experience. Instead, we statistically controlled for driving experience in all of our analyses. Finally, the research design may not have been sensitive enough to detect differences in reaction time or crash rates.

In conclusion, this study clearly demonstrates that both an ADHD diagnosis and texting while driving present serious risks to the driving performance of adolescents. There is a clear need for policy and/or intervention efforts to address these risks. Because texting impairs the driving behaviors of adolescents, as well as adults,[48] it seems that public policy and educational efforts need to focus on putting an end to this behavior while driving. Currently, 39 states have instituted laws making it illegal for anyone to text while driving. An additional 5 states prohibit texting by novice drivers. These legal measures seem appropriate; however, they need to be enforced to be effective. Moreover, efforts to educate adolescents about the impact of texting on driving seem necessary including fostering appropriate parental support.[49] Given the combined impact of ADHD and texting on the driving performance of adolescents, driving interventions that target adolescents with ADHD are required.

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