Young Adults with Attention Deficit Hyperactivity Disorder (ADHD): The impact of secondary tasks on driving performance

Bryan Reimer* (1,2), Joseph F. Coughlin(1), Ronna Fried (2), Joseph Biederman (2)

(1) AgeLab & New England University Transportation Center
Massachusetts Institute of Technology
77 Massachusetts Avenue, Rm E40-291
Cambridge, MA 02139
Email: reimer@mit.edu; coughlin@mit.edu
*corresponding author

(2) Pediatric Psychopharmacology, Massachusetts General Hospital
15 Parkman St., Warren 705
Boston, MA 02114
Email: rfried@partners.org; biederman@helix.mgh.harvard.edu

Abstract

Objective: Young adults with Attention Deficit Hyperactivity Disorder (ADHD) are at higher risk for being involved in automobile crashes. Driving simulators have been used in a variety of contexts to categorize a number of deficits in performance exhibited by drivers with ADHD. Recent research focuses on non-distracted driving. However, in-vehicle infotainment and communications systems are known to further contribute to a driver's risk of collision. This paper explores the impact of secondary tasks on the driving performance of individuals with and without ADHD.

Methods: Data are drawn from two portions of a validated driving simulation that represent the periods before, during and after participation in a secondary task. Secondary tasks include a cellular phone task administered in a high stimulus setting and a working memory task presented during low stimulus driving. Data from drivers with and without ADHD was compared.

Results: When compared to the control group, drivers with ADHD have more difficulty performing the cellular telephone task but fail to modulate their driving in a way that compromises safety. Highway driving performance is impaired in individuals with ADHD. The degree of impairment increases while participating in a working memory task.

Conclusions: The results suggest in low stimulus driving, attention to the secondary task substantially impact the performance of ADHD drivers.

Introduction

This paper addresses the impact of non-visual secondary tasks on young adult drivers with attention deficit hyperactivity disorder (ADHD). Since the early 1900's researchers have debated the importance of inattention as a factor in automobile crashes (Trott, 1930 as cited in Goodman et al.1997). The locus of an operator's visual attention to non-driving activities is easy to identify. Drivers rarely shift their visual attention away from the road for more than 1.6 seconds (Sodhi, Reimer, & Llamazares, 2002; Wierwille, 1993). Cognitive distractions are different. With cognitive distractions, an operator's eyes may be directed toward the road but the focus of attention may be elsewhere (Reimer et al., 2007; Sodhi et al., 2002). The length of cognitive distractions are often longer and drivers are sometimes not fully aware of the of the distraction (Hunton & Rose, 2005; Lesch & Hancock, 2004). Although drivers of all ages fail to appropriately divide attention between driving and secondary tasks, younger drivers are more vulnerable to distraction (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

Studies using surveys and RMV questionnaires show individuals with ADHD have poorer driving histories than subjects with other psychiatric disorders (Murphy, 1996) and display substandard driving habits than control subjects (see Barkley, 2004; Barkley & Cox, 2007; Jerome, Segal, & Habinski, 2006 for review). The ability to focus attention over longer periods of time and to modulate attention between multiple tasks is impaired by ADHD (Barkley, 1998). Driving simulation studies show differences in performance between individuals with ADHD and controls or community samples. Additionally, driving simulations have substantiated the use of medication for improving performance (see Barkley, 2004; Barkley & Cox, 2007; Jerome et al., 2006 for review). Two studies, Laberge, Ward, Manser, Karatekin & Yonas (2005) and Reimer, D'Ambrosio, Coughlin, Fried, & Biederman (in press) address the ability of drivers with ADHD to perform under driving conditions associated with inattention in normal drivers.

Laberge et al. (2005), evaluates the performance of ADHD drivers completing secondary tasks such as: adjusting fan settings, changing track numbers on a CD player and participating in a simulated hands-free cell phone conversation. Results of the study fail to confirm the initial hypothesis that "distraction would compound the impairments of ADHD." Several potential limitations contribute to these results. First, the sample size is small for the analysis of driving simulation data (7 ADHD and 6 Controls). Second, it is clinically unacceptable to use self diagnosis of ADHD. Third, the study did not control for prescribed ADHD medication. Finally, the complexity of tasks largely comprises operations that are considered as an acceptable level of distraction (Sodhi et al., 2002).

The objective of this study is to explore the impact of cognitive distractions on younger drivers with ADHD. The data represent two components of a dual task experiment presented sequentially during a validated driving simulation (Reimer, D'Ambrosio, Coughlin, Kafrissen, & Biederman, 2006). In the urban driving portion of the simulation, participants participated in a naturalistic cellular phone conversation. Subsequently, a segment of Seidman's (1998) continuous performance task (CPT), was administered to participants driving on a four lane highway. It is expected drivers with ADHD would show inferior performance under single task conditions compared to the control group. In addition, this research hypothesized ADHD drivers would have more difficulty managing the requirements of the dual task situation resulting in a larger decrease in driving performance than the control group.

Background

The National Highway Transportation Safety Administration's 100 car naturalistic driving study (Klauer et al., 2006) identifies driver inattention as a causative factor in 78 percent of the crashes and 65 percent of the near crashes. Younger and less experienced drivers have higher involvement in inattention related crashes. Calculating causation of accidents or near misses, Klauer et al., (2006) includes driving-related inattention to the forward roadway and non-specific eye glance away from the forward roadway with the traditional modes of driver distraction (i.e. engagement in a secondary task, and driver drowsiness). To enhance internal validity, studies of inattention often investigate each of these classifications separately. Despite the inverse relationship between inattention and safe driving, the degree to which secondary activities in the car distract individual drivers varies greatly. Increased technology in the driver's domain (e.g. cell phones, navigation systems, collision avoidance systems, and entertainment systems) makes it is increasingly important to understand how attention disorders, such as ADHD may affect a driver's ability to interact with or resist in-vehicle distraction. ADHD is known to be a problematic disorder diagnosed in childhood.

ADHD persists into adulthood in a substantial number of childhood cases (Faraone, Biederman, & Mick, 2006). It is estimated that at least four percent of adults in the United States are afflicted with ADHD (Faraone & Biederman, 2005). Data from clinical and community samples reveal ADHD in adults is associated with high levels of morbidity and functional impairment (Biederman, 2004; Wilens, Faraone, & Biederman, 2004). A key area of dysfunction observed with ADHD is impairment in motor vehicle operation. An emerging body of literature shows adverse outcomes with ADHD drivers. Drivers with ADHD are more likely than drivers without ADHD to commit traffic violations. Adolescents and young adults with ADHD are more likely to be involved and at fault in automobile accidents. For a review on the topic of ADHD drivers refer to Barkley (2004) Barkley & Cox (2007) and Jerome et al. (2006) .

Despite an increased risk of automobile accidents among individuals with ADHD, little research provides insight into what impairments in driving performance are linked to collision causality (Reimer et al., in press). As noted earlier, inattentive driving has a significant influence on automobile accidents. However, interactions between driver inattention and medical conditions that impact regulation of attention are yet to be adequately investigated. In a recent review, Barkley & Cox (2007) note in-vehicle distractions may increase the risk of crashes for individuals with ADHD. On the other hand, their review fails to illustrate a study documenting this interaction. There is however, one study addressing this topic. Laberge et al. (2005), hypothesize that individuals with ADHD are more likely to be distracted by in-vehicle technology or cellular phone conversations. This paper expands upon previous research on ADHD drivers in a manner consistent with work of Laberge et al. (2005). In addition, this research integrates methods defined in the human factors and psychology literature on inattentive driving. The combination of established methods of studying inattentive driving and a population likely to exhibit these traits should provide a more in depth insight to the potential of adverse driving outcomes in ADHD drivers.

Methods

Participants

Two groups of participants were recruited for this study. Participants with and without ADHD were required to be between the ages of 17 and 24, with a minimum of one year of driving experience. All ADHD participants met full DSM-IV criteria and had symptom onset in childhood and persistent symptomatology into adulthood. Controls were included in the study if they failed to meet the criteria for ADHD and endorsed fewer than three ADHD symptoms at any level of severity. Participants were required to be English speakers and have an IQ greater than or equal to 80. Community advertisements and clinical referrals to an adult ADHD program were used for recruitment. Participants were required to sign consent forms from two local institutional review boards.

Apparatus

The driving evaluation was completed in the MIT AgeLab Driving simulator. The simulator is comprised of a full cab 2001 Volkswagen Beetle with a working OEM brake, accelerator, steering wheel and speedometer. The cab is situated in front of a projection screen to provide a driver with approximately a 40 degree view. Graphics are computed based upon data captured from the vehicle controls and roadway geometry at 20 HZ through STISIM Drive and STISIM Open Module (Allen, Rosenthal, Aponso, Harmsen, & Markham, 2002). In addition to graphical updates, STISIM drive provides drivers with a more realistic feeling with force feedback through the vehicles steering wheel and the sound of engine noise through the vehicle’s sound system. During the course of the simulation, secondary tasks were overlaid on the engine sound.

Procedure

Participants first reported to the Pediatric Psychopharmacology Unit at the Massachusetts General Hospital for consent and clinical screening. Eligible participants were scheduled for a driving assessment at the Massachusetts Institute of Technology AgeLab. ADHD participants taking medication for their disorder were instructed by the clinician not to take the medication on the day of their driving assessment. In the driving assessment, participants first completed a seven mile (approximately 10 minutes) accommodation drive in the simulator. The accommodation period used a slow increase of the posted speed limit and visual complexity to reduce simulator sickness. Participants exited the simulator to complete a set of surveys capturing driving histories, behaviors, health history, and demographics.

After completing the surveys, participants drove 35 miles through a validated simulation protocol that included a number of sequential components. Data was drawn from two portions of the protocol: high stimulus “urban” driving and low stimulus “highway” driving (for additional details on the design of the simulation see Reimer et al. 2006). The posted speed limits for urban and highway driving were 35 MPH and 65 MPH, respectively. The urban and highway portions of the protocol were divided into three sections to represent the periods before, during and following a secondary task. Secondary tasks included a cellular phone call (Reimer et al., 2007) and a working memory task (CPT) (Seidman et al., 1998). Participants performed the cellular phone task in the urban portion of the protocol and the CPT in the highway portion. Following the drive, participants completed a survey assessing their experience in the simulator.

Forty dollars was offered as compensation for participation. In addition, $60 was offered as incentive for driver performance. The incentive was split equally into three components: performance of the cognitive tasks, avoiding traffic citations and collisions, and completing the simulation in less than 45 minutes (Reimer et al., 2006).

Data Analysis

Scores on the cellular phone task were computed on a ten-point Likert scale. A composite score on the CPT was computed as a ratio of the number of omissions, false positives, and delayed responses over the total number of presented stimuli. To account for varying driving speeds when sampling in the time domain, driving performance measures were normalized over 25 foot sections of roadway before computing means and coefficient of variation on velocity. For each of the three periods in the urban and highway driving segments a composite mean velocity and coefficient of variation on velocity were computed. Each urban segment spanned 5,000 feet and each highway segment spanned 15,000 feet. The coefficient of variation was computed to control for the confounding effect of unequal average velocities on the speed control. Extreme outliers in each group were converted to missing values using a box plot analysis. Comparisons of driving performance measures were computed using a 3 (period) x 2 (ADHD) Mixed ANOVA with period (before, during and after the cognitive task) as a within-subject factor and ADHD status as a between-subjects factor. Post hoc pairwise comparisons were evaluated using a Bonferroni adjustment. A Greenhouse-Geisser correction was used to adjust the degrees of freedom in models violating assumption of sphericity.

Results

Sample

Sixty participants (25 ADHD) completed the study. Twenty-six (9 ADHD) participants were female. The average age of ADHD and non ADHD participants was 20.56 (S.D. = 2.18) and 20.66 (S.D. = 1.89) years respectively. Gender ($\chi^2_{(1)} = 1.40$, $p > 0.05$) nor age ($F(1, 58) = 0.034$, $p > 0.05$) varied between the groups of participants. Three additional participants were enrolled but failed to complete the driving simulation due to sickness (n=2) and technological problems (n=1).

Participants with ADHD reported driving slightly more frequently ($F(1, 57) = 3.50$, $p < 0.10$) and significantly more miles per year ($F(1, 45) = 9.96$, $p < 0.01$) then those without ADHD. Fourteen of the ADHD participants and 12 of the non-ADHD participants reported being involved in an automobile crash in the past five years ($\chi^2_{(1)} = 3.34$, $p < 0.10$).

Part 1: Cellular Phone Task

Participants without ADHD outperformed those with ADHD on the cellular phone task ($F(1, 53) = 6.36$, $p < 0.05$). Scores for participants without ADHD ranged from zero to nine points with a mean of 4.81 (S.D. = 3.03) points. Participants with ADHD scored between zero to eight points with a mean of 2.96 (S.D. = 2.12) points.

Results from the urban driving simulation showed a significant positive effect of period on driver's forward velocity ($F(2, 114) = 13.07$, $p < 0.01$). Pairwise comparisons showed drivers slowed during the dual task condition and traveled faster in the period after the task than before. Analysis for the coefficient of variation was not significant. Drivers with ADHD paused for significantly longer than those without ADHD at a stop sign ($F(1, 41) = 4.19$, $p < 0.05$). Period also significantly affected pause time ($F(1.69, 69.35) = 3.71$, $p < 0.05$). A decrease in pause time appeared in the period following the dual task (pairwise comparisons: before and after $p < 0.10$, during and after $p < 0.05$). Acceleration after stopping varied by ADHD status ($F(1, 41) = 5.28$, $p < 0.05$) and period ($F(2, 82) = 15.59$, $p < 0.01$). Drivers with ADHD accelerated slower then those without ADHD. Acceleration appeared to increase across the three periods, which indicates adaptation to the simulator.

Part 2: Continuous Performance Task

An analysis of performance on the CPT failed to show any significant differences between participants with and without ADHD. Participants without ADHD committed errors on 27% (S.D. = 14%) of the targets while those with ADHD failed to perform correctly in 24% (S.D. = 16%) of the targets.

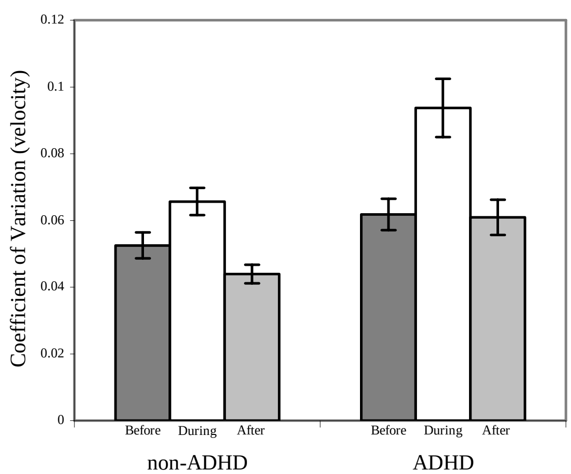

Figure 1: Mean and standard errors (± SE) of coefficient of variation of driving speed as a function of ADHD status and period (before, during, and after dual task)

Results from the highway portion of the simulation showed a significant effect of period on velocity ($F(1.46, 83.25) = 5.86$, $p < 0.01$). All drivers slowed when presented the dual task ($p < 0.10$) but drove faster in the period after ($p < 0.05$). There was no difference in velocity in the period before and after the cognitive task. A significant effect of ADHD was found on coefficient of variation of driving speed ($F(1, 57) = 9.74$, p

< 0.01). A main effect of period (F(1.69, 96.09) = 37.89, p < 0.01) showed the CPT tasks impaired speed control across both ADHD and control subjects (pairwise comparisons: before and during p < 0.01, during and after p < 0.01 and before and after p > 0.05). In addition, as illustrated in Figure 1 a significant ADHD * Period interaction (F(1.69, 96.09) = 3.96, p < 0.05) shows a larger increase in the coefficient of variability on velocity among participants with ADHD during the CPT than among participants without ADHD.

Conclusions

This is the second study to investigate the affect of ADHD on driving performance under dual task conditions. It extends research by Laberge et al. (2005) with a larger sample, more defined set of secondary tasks encompassing a broader range of attentional demands, and different driving contexts. A different pattern of driving performance exists in ADHD drivers across the two portions of the experiment. In the highway portion of the experiment, differences in the coefficient of variation on velocity suggest drivers with ADHD have underlying difficulty with speed control. This result is consistent with a number of published studies (see Barkley & Cox, 2007; Jerome et al., 2006 for review) suggesting ADHD impairs driving performance. In urban driving, differences in the performance of ADHD drivers appears in the time used to observe stop signs and rate of acceleration following the pause. This result does not substantiate causality for the higher risk of automobile accidents observed in earlier studies. However, it does indicate ADHD drivers have difficulty regulating attention between driving and secondary tasks. For example, the driving task may require less attention when a driver is paused at a stop sign in the simulation. During this period, ADHD drivers may unknowingly attend to non-driving related tasks. As a result, longer pause and slower acceleration can be observed before full attention is again devoted to driving the simulator. It should be noted that in typical studies longer pauses and slower acceleration are interpreted as a safe driving behavior.

Differences in the coefficient of variation on velocity in the highway portion of the protocol appear to support earlier results in Reimer et al. (in press). Reimer et al. (in press) characterizes ADHD drivers in situations of low attentional demands. This study found that in fatigue inducing conditions more drivers with ADHD than controls were involved in an accident. The results of these studies combine to suggest ADHD drivers fail to perform adequately in situations where the driving task does not demand a high level of attention.

Inconsistent with this study's expectations but confirming results in Laberge et al. (2005), under the dual task condition ADHD drivers appear to balance the requirements of the cellular phone task in a way that results in a similar decrease in driving performance as the control group. A decrease in task performance does appear between the ADHD and control groups. The findings of these studies fail to provide evidence supporting the hypothesis that ADHD drivers have difficulty regulating attention during a cellular telephone conversation in a way that compromises driving safety differently than non-ADHD drivers.

As illustrated in Figure 1, results from the second part of the experiment confirm our initial hypothesis suggesting the dual task situation will result in a larger decrease in driving performance for drivers with ADHD. ADHD participants are known to have lower scores on the CPT (Seidman et al., 1998). However, the performance of ADHD drivers on the CPT in this experiment did not vary from controls. These findings combine to suggest that in less demanding driving conditions ADHD drivers devote higher levels of attention towards a secondary task compromising driving performance.

In conclusion, this paper indicates certain types and complexity of secondary tasks, when combined, in specific driving situations can exploit deficiencies in an ADHD drivers' performance. This paper highlights the need for additional research focusing on understating the context of the driving environment and the potential impact it may have on the distraction of ADHD drivers. Limitations in this pilot study include the failure to counterbalance the environments, collect baseline measures of cognitive tasks performance, and the small sample size.

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