ADHD TEEN DRIVER EVALUATION

EXTENDED ABSTRACT

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ABSTRACT

Motor vehicle crashes are the leading cause of death for young drivers age 15-20 in the U.S. As a result, a significant amount of researcher has focused upon the causes of young driver crashes. Often cited within the literature are findings that teens are less likely to pay attention to forward roadways, are less likely to anticipate a hazard, and have difficulty controlling driving behaviors, such as speeding. While many teens struggle with self-regulation as well as developmental limitations, teens with cognitive disabilities such as Attention Deficit Hyperactivity Disorder (ADHD) have additional challenges. This research identifies the differences in the driving skills of ADHD novice drivers and neurotypical (NT) novice drivers, especially the skills of hazard anticipation, attention maintenance and hazard mitigation.
1. BACKGROUND

1.1. Teen Driver Challenges

Motor vehicle crashes are the leading cause of death for young drivers age 15-20 in the U.S. The latest available data from the National Highway Traffic Safety Administration (NHTSA) (2011) indicates that 10.0% of all drivers involved in fatal crashes are between the ages of 15 and 20 (1) whereas drivers in this age group make up a much smaller percentage of the total population of drivers. Within the age range so identified, research has shown that due to their limited experience, 16 and 17 year old drivers have a significantly higher crash rate than the safest driving cohorts. The most critical period is the first six months after a teenager obtains a driver’s license (2). As a result of these data, teen drivers have become the focus of myriad research efforts attempting to identify the driving attributes of, behaviors of, and specific scenarios where younger drivers are involved in crashes. Figure 1 characterizes some of the existing research focused on young driver crashes. Teens struggle with self-regulation as well as developmental and cognitive processing limitations. Teens with cognitive disabilities have additional challenges. For example, ADHD increases the struggles that they may have with learning, executive functions (decision making processes) and self-regulation skills.

<table>
<thead>
<tr>
<th>Driving Attributes</th>
<th>Driving Behaviors</th>
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<tr>
<td>Teens are generally less likely to:</td>
<td>Teens are more likely to be involved in crashes with:</td>
</tr>
<tr>
<td>• pay attention to forward roadway during secondary in-vehicle tasks (3, 4);</td>
<td>• speeding (7);</td>
</tr>
<tr>
<td>• anticipate location of unexpected hazards (5);</td>
<td>• alcohol (1, 8);</td>
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<tr>
<td>• perform basic vehicle control tasks well like speed control, acceleration, and lane position (6, 7).</td>
<td>• passengers (9, 10); and</td>
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<td></td>
<td>• distracting in-vehicle behaviors (i.e., cell phone or PDA) (11, 12).</td>
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Figure 1. Overview of Younger Driver Research

1.2. ADHD Specific Driver Challenges

Many teens have learning disabilities and other medical conditions that can affect their ability to learn and transfer skills. ADHD is reportedly present in 3-7% of school aged children with males being over represented in this group (13,14). The primary challenges facing these teens are with regard to executive function and decision making. Other cognitive skills are affected by this neurological disorder and behavioral deficits can manifest themselves as outlined in the left panel of Figure 2. Not surprisingly, the behavioral deficits associated with ADHD have a specific impact on the skills critical to driving. Difficulties with these skills in turn lead to inflated crash statistics (right panel of Figure 2). For example, research suggests that ADHD teen drivers are seven times as likely to have been in two or more crashes and four times as likely to have been at fault for the crash in which they were involved (24).
ADHD Attributes | ADHD Driving Impacts
--- | ---
Cognitive impacts of ADHD: (13-16) | Impacts on Driving task: (16)
- Distractibility, lack of focused attention
- Difficulty in organizing tasks or subject matter
- Difficulty managing emotions or regulating impulsivity
- Inability to filter out external stimulus or sensory inputs
- Difficulty with accessing working memory or recall
- Difficulty with or processing speed
- 8 X more likely to lose license
- 4 X more likely by involved in a collision
- 3 X more likely to sustain serious injury
- 2 – 4 X more likely to receive a motor vehicle violation

**Figure 2. Overview of Applicable ADHD Driver Research**

1.2.1. Literature

Given the above behavior deficits, teens with ADHD are at a greater disadvantage when learning to drive. A case can be made that the teen ADHD crash statistics are inflated because driving instruction is not targeted towards their particular deficits. Driving is considered a multilevel task that involves skill competency on and across three levels: operational, tactical and strategic. At the operational level, quick responses, attention, concentration, visual scanning, visual-motor integration and spatial perception are required. During the tactical level of a driving task, where executive function is particularly important, a person must learn to anticipate hazards, maintain attention, and mitigate hazards when they do occur. At the strategic level, decisions regarding trip planning, route choice or time of day of travel are required. Any neurological disorders or deficiencies that could affect these three core competencies could negatively impact the driving task (14,17). ADHD teens struggle with some of these core competency skills required for a successful driving experience.

In order to understand the impact of this disorder on the driving task, a hierarchical graphic was developed by Dr. Barkley in 2004. As seen the below figure, the driving task can be comprised of three levels of competency; operational, tactile and strategic.

**Figure 3: Dr. Barkley Driving Task**

At the operational level, cognitive functions are required such as; attention, concentration, reaction time, visual scanning, spatial perception and orientation, visual-motor integration, speed of cognitive processing, motor coordination and other neuropsychological abilities that are inherent in driving. (Barkley and Cox, 2007)
At the tactile level, driver behavior, skills and decisions making are required to drive in traffic, adapt speed and make decisions about passing. (Barkley and Cox, 2007)

Lastly the strategic level requires decision and planning ability relating to the actual route or purpose of the route.

Returning to the ADHD symptoms, the primary symptoms of this disorder that could impact the driving task at the operational and tactile levels are issues with inattention and close attention to details, such as speed limit signs, traffic lights, speedometer levels, distraction by external stimuli, such as pedestrians, billboards or workzones and difficulty with sustaining mental effort, such as rural driving environments that require little mental effort.

At the tactile level driver behavior could be greatly impacted by an ADHD diagnosis as they often have difficulty with impulsivity so are prone to quick and often non thought through reactions.

Another concerning symptom of ADHD is failing to follow directions. This could be problematic when teen drivers are learning to drive and also as they become more experienced, driving without regard to laws and regulations or becoming careless.

1.2.2. Driving Simulator ADHD Studies

In a recent study by Reimer, et al. published in 2009, researchers studied the effects of dual cognitive tasks on young adult drivers with ADHD in a simulated environment. This research focused on identifying potential issues with additional cognitive workload as it relates to the visual task of driving to non-driving tasks. The study group consisted of 63 youth ages 17 to 24 with one year of driving experience, 25 with ADHD and 35 as a control. An important note, of the 25 ADHD subjects, 12 were being treated with stimulant medication at the time of the experiment, but were asked to abstain during the day of the simulation. The participants also received 40$ of compensation for their time in the study and were offered 60$ of incentive money to simulate reward for good driving behavior. The 60$ was portioned out based on the subjects performance on the cognitive task, the ability to avoid traffic violations and collisions, and completing the simulation in less than 45 minutes.

The research was conducted at the MIT Age Lab, using a full size Volkswagen and STISIM Drive and STISIM Open technology. Participants were evaluated on two tasks, the first included a simulated cell phone call to book a dr. appointment and the second was to respond when a target letter was identified over a recorded series of letters. Two driving scenarios were created, the first "high stimulus" driving scenario replicated an urban driving environment while the second, "low stimulus" driving scenario replicated highway driving. The cell phone task was evaluated during the urban driving environment at 35 MPH and the target letter task in the highway portion at 65 MPH.

During the urban portion of the experiment, the ADHD drivers driving performance was comparable to the control group, however they did score significantly lower on the phone task. The ADHD drivers also drove at higher speeds when not involved with a secondary task for a greater distance. In addition, the pause at the stop sign's were significantly higher for the ADHD group before and during the cell phone call. There was increased velocity at each of the stop signs, but this was not different between the groups. The additional time elapsed during the stop sign, while this typically indicates safe driving behavior, can also be indicative of the ADHD drivers having difficulty between driving and the secondary task of letter selection.

The results of the "low stimulus" experiments indicated that the ADHD drivers had difficulty controlling speed, driving over the speed limit for a much greater distance that the control group.
There was also indication that speed variability was an issue for both groups, however the ADHD group had a greater difference in the variability of velocity particularly in the "before" and "during" portion of the secondary task. Interestingly, the ADHD subjects actually performed slightly better on the secondary task itself. This is particularly interesting finding, as this type of task (letter recognition) can be given to ascertain attention issues. The researchers suggest in low stimulus environments, it may be more difficult for the ADHD teen driver to maintain focus on the driving task which could result in less responsiveness to sudden changes in the environment or the introduction of a hazard. (Reimer, et al. 2008)

Another recent case study conducted by Monahan and Classen et al. and publish in 2013, looked at two pre-driving teens, one with ADHD/ASD and one without to ascertain driving skills and potential mitigation techniques that could be used to help correct pre-driving errors using a driving simulator. The evaluation was conducted at the University of Florida in 2011-2012 using a Dodge Neon Car, running STISIM software. The two participants were allowed a a 7 minute acclimation to the simulator and then a 20 minute main drive with a Certified Driving Rehabilitation Specialist (CDRS) in the passenger seat of the vehicle capturing the drive data. Overall the ADHD/ASD teen made made 44 driving errors compared to the control at 17. The majority of the errors were relative to lane maintenance, speeding and visual scanning during intersections and lane changes. The ADHD/ASD teen approached all 11 of the intersections with excessive speed and ran two red lights. The perspective of this research is from an occupational therapist, and as such, is an attempt to ascertain a pre-driving teen's need in the visual-motor integration, cognitive and executive functions and motor abilities. The Authors suggest that teaching pre-driving skills based on complexity, starting with simplistic functions like lane maintenance, may be a beneficial way to prepare these pre-teens for driving school and subsequent complex driving tasks that involve hazard mitigation.

In a more recent article published by Classen and Monahan et al. the authors focused on assessing the performance and specific driving errors of teens with ADHD using the afore mentioned simulator. For this experiment, researchers included 9 teens with diagnosed ADHD and 22 teen controls, all subjects were age 14-18 years and did not yet have a learner's permit or driver’s license. Similar to the last study, an OT-CDRS sat in the passenger seat and recorded seven driving errors; lane maintenance, speed regulation, yielding, signaling, visual scanning (displaying scanning of the surrounding environment while driving), adjustment to stimuli, and gap acceptance. The simulator recorded, off-road accidents, collisions, pedestrians, hit, speed exceedances, speeding tickets, traffic light tickets, stop signs missed, centerline crossings, road edge excursions and DA response times. (Monahan et al. 2014) It is important to note, that 6 of the participants were on prescription drugs to treat ADHD during this experiment.

The results indicated that the ADHD group performed significantly worse on the clinical testing portion, visual function test, as related to the right eye visual acuity, right peripheral field and selective attention on the UFOV subtest 3 and motor performance measured on the BOT2. (These tests relate to Occupational Therapy - The tests measure attention. I will have to look closer at these tests in order to understand the importance.) However, the simulator data, which represented operational driving functions, did not show any any significant difference between the ADHD group and the control group. They assessed that the ADHD group had more visual scanning errors and speed regulation errors, based on observation and the ADHD group made more adjustment to stimuli errors. The response to stimuli errors were measured based on the ability to respond to the driving environment.
Taking into account the clinical testing combined with the simulator findings, the researchers found correlations between speed regulation errors and depth perception. They indicated this was not a surprising finding, as speed regulation is dependent on motor performance, planning, sequencing and selective attention, however they indicate that this requires further investigation. (Classen, et al. 2014)

To date, the research surrounding teens with ADHD has been focused on assessing the fundamental driving deficiencies operationally and tactually. Researchers have found and confirmed that the symptoms of ADHD impact a teens driving ability as seen in difficulty in response time to hazards, lane maintenance, speed maintenance and speeding for greater distances in situations where their cognitive functions are split between a secondary task. Secondary tasks are particularly troublesome for this subset of the population and present additional difficulty in distractibility and focus. Additionally, research has indicated a deficiency in the right field of vision.

One question is whether these studies can pin point deficiencies in driving skills that should be explored further, or if the shift in research focus should now be aimed at developing training to mitigate the observed problem areas. In a recent article published in JAMA Pediatrics in 2013, the authors ask the question, " Are We Doing Enough to Prevent the Perfect Storm? Novice Drivers, ADHD and Distracted Driving". They indicate that graduate licensing may offer the additional time and space for more training as well as the need for a tailored training program to help address these needs in the ADHD teen population. (Winston, et al. 2013)

2. EXPERIMENTAL DESIGN

This experiment will measure; attention maintenance, hazard anticipation, hazard mitigation, & roadway scanning in different types of driving environments. Two groups of ADHD and non-ADHD drivers are included, those 16-18 and those 30-55 years old.

Attention maintenance, reaction time and hazard mitigation strategies will be studied in simulated scenarios. The drives have been programmed to differentiate driving conditions to engage the drivers at different levels of intensity using different levels of traffic density and roadway geometry to assess the relation between distracted driving and different driving demands (as determined by the levels of traffic and types of road geometries). Hazards are presented scenarios to gage driver response and mitigation. The driving environment is intended to replicate Route 116 in Amherst, Massachusetts with a mix of residential and business in close proximity to the roadway. Vehicle and eye tracker measures will be collected including participants’ attention to the forward roadway and their speed, speed deviation, and lane position.

Engaging or High Load (HL) driving environments consist of: Curves; lane position and velocity require careful monitoring; To create levels of an engaging environment - the roadway geometry changes from tangent to curve and traffic is included.

Not Engaging or Low Load (LL) driving environments consist of: Tangent roadway; lane position and velocity do not require careful monitoring; To create a lower level of engagement, traffic will be removed.

Sixteen scenarios were developed to evaluate hazard perception and mitigation. Each of the 8 drives contains at least two hazards. The hazards and drives were randomized to avoid any confounding or learning effect that a participant could experience.
2.1.1. Participants.
A total of 72 participants across two age cohorts will take part in Phase I of the study, Figure 3. Of these, 36 will be teenage drivers between the ages of 16 and 18 and the other 36 will be experienced adult drivers between the ages of 30 and 55. Within each of the two age cohorts, half (18) of the drivers will have received a medical or educational diagnosis of ADHD and the other half (18) will have no prior history of an ADHD diagnosis. To mitigate potential sample bias, both ADHD and non-ADHD participants will be recruited from the same geographical areas with an effort made towards matching samples on age, gender, cultural, and socioeconomic variables.

2.1.2. Method.
A series of previously validated simulator drives will be utilized that assess participants’ skills in hazard anticipation, hazard mitigation, attention maintenance and roadway scanning of peripheral hazards on both straight and curved sections, at different types of intersections, and in different traffic environments. Participants will be given various in-vehicle tasks (e.g., find change for a toll booth) and various cognitive loading tasks which allow them to keep their attention on the forward roadway (e.g., a cell phone task). Within each of the cohorts listed in Figure ?, vehicle behaviors, driving behaviors and eye tracking protocols will be recorded for the purposes of investigating differences between population.

2.1.3. Procedure.
(a) Consistent with IRB procedures, all participants will be consented or assented (assent is the term used for the agreement of someone under 18 years of age to participate in a study) and, in the case of teens under the age of 18, parental consent received. (b) All 72 participants will be seated in the lab’s driving simulator and then fitted and calibrated with a lightweight mobile eye tracking device. The eye tracking system contains a head-mounted scene camera which records the view out the windscreen of the simulator cab (a 1995 Saturn sedan) and the computer overlays a crosshair on the video output which represents the participant’s point of gaze. (c) After a short practice drive in the simulator, each participant will drive a series of simulator runs, each lasting 4 to 8 minutes, with a total of 30 to 45 minutes spent on the simulator. The simulator runs will each assess the driver’s hazard anticipation, hazard mitigation, attention maintenance, and roadway scanning skills using both eye tracking, driving performance and verbal protocols (the participants will call out a potential hazard when seen). Vehicle variables such as following distance, lane position, speed, braking and acceleration, and steering inputs will be automatically recorded by the simulator for each participant. Driver variables (foot position, hand position) will be recorded by appropriately positioned cameras mounted inside the vehicle.
3. ANTICIPATED RESULTS

For each drive, it is anticipated that the following will result:

(a) Scanning patterns. Based upon prior research, it is expected that the roadway scanning behavior of teens with ADHD will be less focused than that of non-ADHD teens in the LL drives with reduced driver engagement. In the HL drives, we expect the ADHD teens to perform better or equal to that of the control group. Provided individuals with ADHD are characterized by a predisposition for inattention, hyperactivity and impulsivity, it would be expected that their gaze patterns within the environment would be more random (less strategic) than those of non-ADHD individuals (20). In driving, visual-spatial entropy is a measure of the randomness (non-redundancy) of gaze patterns across pre-defined static state-spaces around the vehicle as computed using a 1st order Markov Chain entropy metric (23). We expect that measures of visual entropy would be higher for ADHD individuals, especially so for teens. Given the HL geometric and driving engagement variables, we expect the scanning patterns will be more focused.

(b) Hazard anticipation. We also expect that ADHD teens will miss more hazards than non-ADHD teens, specifically in the LL drives. In part this is because of the increased entropy. But in part it is also because ADHD teens, even when they gaze upon a potential hazard, are less attentive and therefore may become distracted and not anticipate the hazard. With a change in the driving environment, it is expected that the ADHD teen will be more engaged in the driving task and more likely to anticipate the hazard.

(c) Attention maintenance. We expect that during the performance of in-vehicle tasks the ADHD teens will take many more long glances due directly to the ease with which they can become distracted from the driving task specifically in the LL drives. We also expect that they will be less effective at dividing their attention when given a simulated cell phone task causing them to miss critical information on the roadway (such as the presence of a hidden pedestrian or vehicle) and will scan less to the side when engaged in secondary takes (an interaction between cognitive workload and visual entropy).

(d) Hazard mitigation. Because of increased difficulty with executive functioning and impulsivity, we expect ADHD teens in the LL drives, will make more driving errors, choose more risky headway and turning gap sizes, show a wider variance in lane keeping, and brake harder and later than non-ADHD teens.

(e) Effects of age. Because evidence suggests the effects of ADHD on driving seem to decrease with age, we expect there to be marginally significant or no differences between adult drivers with ADHD and those without in both the LL drives and HL drives.

3.1. Next Steps

Overt December of 2015, participants have been scheduled to participate in this study. Data and findings will be analyzed and are highly anticipated.
REFERENCES


