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Final Report

Distracted Driving: It is not always a choice

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Michael P. Hunter[1], Gregory M. Corso[2], Michael O. Rodgers[1], F. Atiyya Shaw[1], Sung Jun Park[1], JongIn Bae[1], Zoe Becerra[2], William Woolery[1]
[1] School of Civil and Environmental Engineering, Georgia Institute of Technology; [2] School of Psychology, Morehead State University

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DISCLAIMER

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LIST OF AUTHORS

Michael P. Hunter[1], Associate Professor (michael.hunter@ce.gatech.edu)
Gregory M. Corso[2], Professor and Chair (g.corso@moreheadstate.edu)
Michael O. Rodgers[1], Principal Research Scientist (michael.rodgers@ce.gatech.edu)
F. Atiyya Shaw[1], Graduate Research Assistant (atiyya@gatech.edu)
Sung Jun Park[1], Graduate Research Assistant (sungjunpark@gatech.edu)
JongIn Bae[1], Graduate Research Assistant (jamesjonginbae@gmail.com)
Zoe Becerra[2], Undergraduate Research Assistant (zmbecerra@moreheadstate.edu)
William Woolery[1], Undergraduate Research Assistant (woolery@gatech.edu)

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[1]School of Civil and Environmental Engineering, Georgia Institute of Technology
[2]School of Psychology, Morehead State University

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ABSTRACT

Driver distraction negatively impacts both driver performance and crash rates. As roadway systems become more complex, with mixed modes of transportation, varied levels of automated technology, and increased visual clutter inhabiting a shared environment, it is even more important to study the effects of roadway distractors on performance, particularly for vulnerable road users who may have increased risk for distraction. As such, the primary objective for this research project was to identify the influence of roadside distractors on the performance of drivers with and without attention deficit tendencies. A driving simulator experiment was developed to obtain driver performance metrics across simulated scenarios that included roadside distractors (billboard, work zone, accident scene, and police cars) located in the vicinity of a performance task. Results indicated that roadside events have statistically significant effects on variability of lane position and speed. Additionally, drivers with attention deficit tendencies displayed more lane position variability than control group drivers for all roadway segments examined. Of the distractors tested, billboards and work zones were shown to have the most significant impacts on driver inattention, as evidenced by decreased detection time margins and error rates respectively. This study is one of the first to examine the effects of roadside distractors on drivers with and without attention deficit disorders, and lends insight regarding the effects that external distractions can have on driver performance.

EXECUTIVE SUMMARY

As roadway systems become more complex, with increased visual clutter, new automation technologies, and mixed modes of transportation, it is increasingly important to understand the effects of roadside distractors on driver performance. This is especially important for drivers with attention deficit disorders who have increased rates of driving incidents and infractions. As such, the goals for this research study were to (1) identify the influence of roadway events on the performance of drivers with attention deficit disorders, and (2) to analyze the performance of drivers with attention deficit tendencies relative to control group drivers.

A driving simulator experiment was used to obtain driver performance metrics such as lane and speed variability, identification task accuracy, and detection time margins across 15-minute simulator scenarios developed for this study. In each scenario, participants were asked to indicate when they observed a diamond pavement marking in their lane; distractors were placed on the shoulder or side of the roadway near the diamond to allow researchers to observe and identify cases where the participant missed or delayed reporting a diamond or exhibited associated changes in speed and lane variability. A total of 46 participants successfully completed at least one data collection session, and 10 of these participants were found to have attention deficit tendencies, as determined using the Test of Variables of Attention (TOVA).

Mixed model Analyses of Variance were used to analyze performance metrics, with results indicating significant decreases in lane and speed variability in the vicinity of roadside events for all drivers. Drivers with attention deficit tendencies were also found to have significantly greater lane variability than control group drivers across all roadway segments. Furthermore, post-hoc comparisons indicated that drivers had significantly greater detection time margins for all distractors relative to the no distraction event. The dynamic billboard resulted in

the shortest detection time margins across all distractors, and the work zone resulted in the most identification errors across distractors. Such results indicate that roadside distractors do have negative impacts on driver performance, and can be applied to inform design guidance at sites where external distractions are believed to contribute to elevated crash rates.

Whereas the effects of in-vehicle distractions on driver performance have been extensively studied, this research effort represents a unique approach to examining the effects of common roadside distractors on driver performance. The findings lend insight on the effects of roadside distractors along a monotonous roadway, and suggest that future simulated and field studies of external distractors on driver behavior and performance are warranted. Efforts should be made to further explore the practical significance of these results, particularly in relation to safety. Ultimately, it is imperative to continue to study and understand why errors occur in the roadway environment, as it rapidly transitions into an increasingly dynamic and complex shared system.

CHAPTER 1. BACKGROUND

Driver distraction is known to have detrimental impacts on driver performance, with recent statistics from the National Highway Traffic Safety Administration (NHTSA) indicating that 10% of fatal crashes (3179 fatalities) and 18% of injury crashes (431,000 injured) were "distraction-affected" in 2014 (*1*). A significant portion of distracted driving is considered ***voluntary*** (*2*), and is related to in-vehicle driving distractions such as mobile phones (*1-3*). However, there exist ***involuntary*** (*4*) distraction as well, some of which may be attributable to attention deficit disorders (diagnosed and undiagnosed) that can increase the frequency and risk of distracted driving (*5*). Additionally, while there has been less research on external (outside-of-vehicle) driving distractions relative to in-vehicle distractions, roadway environment factors and distractors are known to affect driver performance. This is evidenced by both simulator performance metrics (*6-14*) and crash data (*15-19*). As such, the goal for this research was **to investigate the effects of roadside distractors on performance of drivers with and without attention deficit tendencies.**

To achieve this goal, a driving simulator experiment was developed that allowed researchers to obtain performance metrics in the vicinity of several roadside distractors. Participants were asked to indicate when they observed a diamond pavement marking (similar to an HOV diamond) in their lane as they drove through a simulated environment. Distractors were placed on the shoulder or side of the roadway (without interfering with traffic flow) near the diamond to allow researchers to observe and identify cases where the participant missed or delayed reporting a diamond or exhibited associated changes in speed and lane position due to an attention shift away from the roadway.

IMPACTS OF ROADWAY ENVIRONMENT FACTORS AND DISTRACTORS ON DRIVER PERFORMANCE

Crash analysis studies have cited external distractors as a contributing factor in between 23 to 29% of distraction-related crashes (*15; 16*), and have found that such distractors significantly increase the odds of crash occurrence (*17*). Correspondingly, the existing literature suggests that roadway environment factors such as: billboards (*6; 7; 14; 20*), urban/rural environments (*8-10*), intersections (*8; 11; 21*), and increased traffic density (*8; 12; 13; 18; 19; 21-23*), adversely affect driver performance and/or crash rates. However, few studies have examined the performance effects of common roadside distractors occurring independently of each other (*20*).

The distractors in this experiment (billboard, work zone, accident scene, police cars) were selected based on findings from the literature. Specifically, prior simulator studies have found that billboards adversely affect lateral control and workload (*7; 14*), while increasing reaction time and redirecting vision away from the roadway (*6; 7; 14*). Additionally, the presence of work zones has been shown to significantly increase the rate of crashes (*24; 25*), with some evidence to suggest that driver distraction is a contributing factor to this increased risk (*24*). Finally, although prior simulator studies are not known to have explicitly examined the effects of roadside accidents, police cars, and other emergency vehicles on driver distraction, these events have been examined in crash studies, all of which report negative effects of external distractions on driver performance (*1; 15-17*).

IMPACTS OF ATTENTION-DEFICIT/HYPERACTIVITY DISORDERS ON DRIVER PERFORMANCE

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that affects an estimated 11% of children between the ages of 4 and 17 (*26*). With high rates of persistence into adulthood, approximately 4% of the adult population (8 million adults) are estimated to have ADHD (*27*), an estimate that is on the rise as the rate of ADHD diagnoses in children increases (*28*). There are three subtypes of ADHD: (1) predominantly inattentive, (2) predominantly hyperactive-impulsive, and (3) a combination of the previous two subtypes (ADHD-C); all of which are associated with symptoms of inattention and impulsivity (*26*), traits that have been shown to negatively impact driver performance (*29-35*). There exists a significant body of literature that has found increased rates of car crashes (*29; 31; 36-40*), speeding violations (*29; 36-39*), and license revocations/suspensions (*29; 36; 37; 39*) for drivers with ADHD, although it is important to note that the magnitudes of these findings vary across studies (*38*). Additionally, it has been found that drivers with ADHD are at an increased risk for multiple collisions and violations, and have greater tendencies to be at fault in a collision (*41*).

A series of driving simulator laboratory studies have explored the effects of attention deficit disorders on driver performance, with many reporting varied results for reasons that may include, among other factors, differences in defining ADHD status and differences in experimental design. Given that ADHD is a disorder usually diagnosed in childhood, a majority of the literature focuses on the effects of ADHD on distracted driving in teenaged drivers, with many examining the effects of various in-vehicle visual (texting) and cognitive tasks (interactive phone conversation) on driver performance. Stavrinos et al. found that drivers (aged 16 to 18) with ADHD-C took less time to complete scenarios while texting, and attributed this to reduced compensation (i.e. speed reduction) during distraction; however, the study did not find significant differences for lane position and speed variability metrics between ADHD and control group drivers (*42*). In contrast, Narad et al. reported increased variability in speed and lane position for adolescents (aged 16 to 17) with ADHD (*43*), while Fischer et al. likewise found that drivers (aged 19-25) with ADHD had increased crashes and steering variability than control group drivers during a simulated drive (*35*).

A dual simulator and self-report study by Reimer et al., found that drivers (aged 16 to 55, Mean Age: 29.5) with ADHD have higher rates of collision in low-stimulus environments such as highways, and also become fatigued more quickly than control group drivers (*40*). This finding was corroborated in a later study, also by Reimer et al., which found that driver performance for ADHD drivers (aged 17 to 24) decreased during a secondary continuous performance task on a monotonous freeway, again suggesting that ADHD drivers may have more difficulty in assigning attention during low-stimuli driving conditions (*44*). Based on these findings, this experiment was set within a rural, monotonous two-lane roadway as detailed below.

CHAPTER 2. RESEARCH APPROACH

This experiment was conducted using the National Advanced Driving Simulator (NADS) MiniSim®, a low to medium fidelity fixed-base driving simulator with a 135° field-of-view (see Figure 2-1). The NADS MiniSim used in this experiment was outfitted with a Logitech G27 steering wheel with Extreme Competition Controls Inc. (ECCI) brake and accelerator control systems. Driving simulator scenarios were developed using Interactive Scenario Authoring Tool (ISAT), the MiniSim's scenario development software. Participants were recruited from a mid-sized public university in the southeastern United States and Institutional Review Board (IRB) approval was obtained prior to implementation.

Figure 2-1. NADS MiniSim® Driving Simulator used for Experiment

OVERVIEW OF EXPERIMENT

Participants attended one training session followed by multiple data collection sessions that occurred on different days. The number of data collection sessions that each participant attended, as well as the time elapsed between sessions varied in accordance with participant availability and equipment reliability. Further details regarding issues faced with equipment reliability are detailed in the participant summary section of this chapter. Unless otherwise noted, only data from the first non-training session was used in this report to maximize the number of participants.

Experiment Sessions

Experiment procedures during the training session included an instructional period, informed consent procedure, near and far range eye exam, color deficiency test, demographic survey, Simulator Sickness Questionnaire (SSQ) accompanied by a 15-minute simulator training drive, and administration of the Test of Variables of Attention (TOVA). The TOVA, a computer-based neuropsychological continuous performance test, measures attention and impulse control; it has been used in research and clinical settings since 1966 (*45*). The clinical version of the visual TOVA was used to obtain a reading of 'Normal' or 'Not Within Normal Limits' for each participant. These results then were used to group participants who showed attention deficit tendencies relative to participants with 'Normal' TOVA scores – hereafter referred to as the control group. Because this test is not recommended for use as a sole diagnostic tool, the results are treated as suggestive of attention deficit tendencies for the purposes of this research study.

For the data collection session, proctors reviewed the task instructions with the participants, followed by the administration of a 15-minute driving simulator scenario. Participants were then given a short self-timed break, after which they drove through a second 15-minute scenario.

Simulator Scenario Design

Five scenarios were developed for this experiment, each containing a series of five events. For each scenario, a simulated two-directional, two-lane rural roadway segment with no horizontal or vertical curvature was used. The lanes were delineated with white edge lines indicating edge of traveled way and beginning of paved shoulder, and the directions of travel were separated with a standard broken yellow centerline. There were two versions for each of the five scenarios, one with a lead vehicle (motorcycle) traveling at 60 miles per hour in the participant's lane, and one with no lead vehicle. A motorcycle was selected as the lead vehicle to ensure that the participants' field of view was not obstructed. Corresponding scenarios (i.e. with and without lead vehicle) were otherwise identical with respect to event order and position. There was no ambient traffic, with the exception of the presence of the lead motorcycle in the applicable scenarios. The route was 15 miles (79200 feet) in length to allow the participants to drive for approximately 15 minutes at the requested speed of 60 miles per hour. Of the two randomly selected scenarios that each participant drove during each data collection session, one contained a lead vehicle while the other did not. In scenarios with a lead vehicle, participants were instructed to follow at a self determined reasonable distance. Each participant drove for five minutes (approximately five miles) at the beginning of the scenario with no events. The training scenario was the same roadway environment used in the experiment; however, it did not have the events.

Events within Simulated Scenarios

Each scenario contained the same five events in randomized order and at varied time points, with time between events ranging from 2 to 3 minutes after an initial five-minute period (see Table 2-1). In this experiment, an event was defined as: a roadside distractor, an HOV diamond pavement marker in the center of the lane, or both a distractor and a HOV pavement marking in the same zone. Of the five events, three consisted of a HOV diamond pavement marking accompanied by roadside distractors, one was a HOV diamond pavement marking unaccompanied by any distractors, and one was a roadside distractor that was unaccompanied by an HOV diamond pavement marking. The four roadside distractors were: (1) several police cars with flashing lights; (2) an active work zone; (3) an accident scene; and (4) a billboard with dynamic graphics located on the left side of the roadway. Appropriate audio effects accompanied the two events with emergency vehicles. With the exception of the distractor that occurred without a diamond, the pavement markings came into view at proximal locations to the distractors. Within each session, the order of events within the scenarios was randomized to limit predictability of event occurrence.

Participants were instructed to respond to the pavement markings by depressing a response button on the steering wheel. There is one lower button on the right, and one lower button on the left side of the steering wheel, which allowed for the equal accomodation of right and left handed drivers. Table 2-1 summarizes a sample scenario in this experiment. Figure 2-2 illustrates the four roadside distractors from the perspective of the driver. At the end of each session, participants were asked a question pertaining to one of the events that occurred (e.g. how many cars were pulled over?).

Table 2-1. Sample Scenario

Event No.	Event	Time relative to Start of Drive	HOV Diamond Occurrence
1	Police Cars	5 minutes +/- 30 seconds	◊
2	Accident Scene	2.5 minutes +/- 30 seconds	
3	No Distraction	2.5 minutes +/- 30 seconds	◊
4	Work zone	2.5 minutes +/- 30 seconds	◊
5	Dynamic Billboard	2.5 minutes +/- 30 seconds	◊

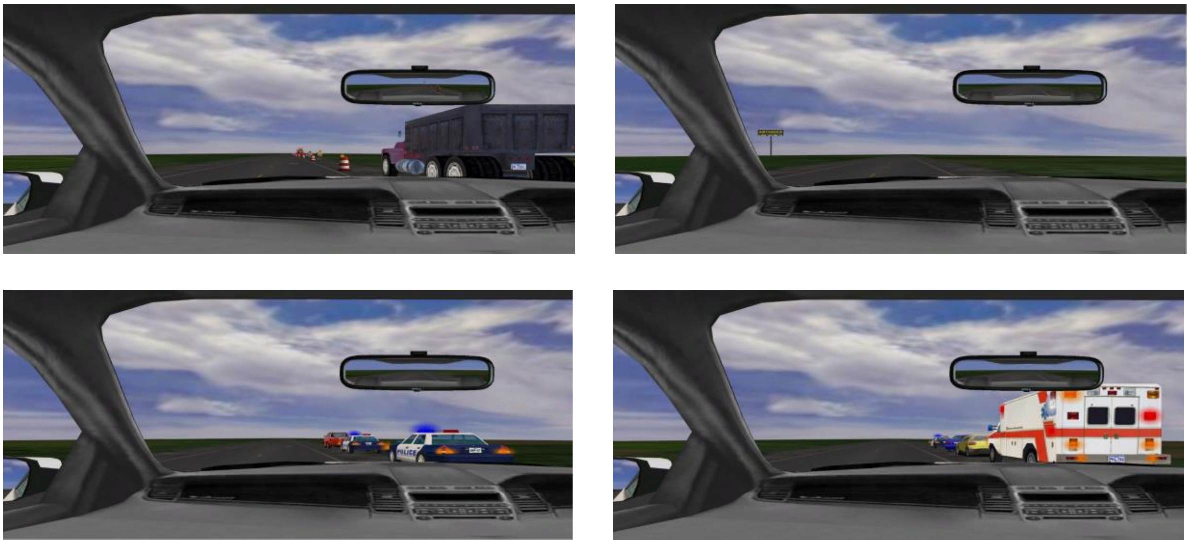

Figure 2-2. Roadside Distractors (Top Left: Construction Work Zone; Top Right: Electronic Billboard; Bottom Left: Police Cars; Bottom Right: Accident Scene).

PARTICIPANTS

Participants were recruited via word-of-mouth and flyers and were reimbursed with a small cash payment ($10) per session or with extra credit in their classes. There were 46 participants (35 females and 10 males), all of whom were verified to have normal or corrected-to-normal vision. No participants were excluded due to simulator sickness. The average age of all participants was 20.5 with 93.5% of participants falling in the 18 to 24 age range (Mean 19.2, S.D. 1.5). The 36 participants who comprise the control group had an average age of 20.9. Of these 36 participants, three self-reported being diagnosed as ADHD by a physician and were on medication at the time of this experiment (Mean age 22); these participants had TOVA scores within normal limits, and were placed in the control group. Although it is recognized that these participants may differ from control participants not on medication, the sample size did not allow for differentiation between these groups, and TOVA scores were used as the sole method of differentiation between attention deficit and control groups. Future efforts will seek to increase the sample of participants with self-reported ADHD and who are using medication. For the ten participants who had TOVA results suggesting attention deficit tendencies, the average age was 18.9 (S.D. 1.3).

Some of the issues faced with equipment reliability over the course of this research project are discussed here, as it affected the participants retained for analysis. During the first round of data collection (Spring 2015), the research team encountered a problem with the memory in the simulator which resulted in the loss of data from all sessions for nine participants, as well as the loss of data from the second session for six participants. During the second round of data collection (Fall 2015), three participants were eliminated due to the simulator not retaining the data from both drives (or the entirety of the first drive) in their first data collection session, and three participants were eliminated due to missing participant records. In six cases, the simulator crashed during one or multiple participants' runs; and participants had to start the scenario over again – in these cases, if the participants had driven less than one third of the run when the simulator crashed, their data on subsequent reruns were kept (three participants were eliminated based on this criteria). As a result of these setbacks, unless otherwise stated, the results are aggregated over Session 1 data only, as this maximizes the number of viable participants. An overview of the participants included in this analysis is presented in **Error! Not a valid bookmark self-reference.** After research and communication with the simulator vendor, the team recommends that the data collection process be monitored by a program running parallel to the simulation that can stop the drive when the data acquisition program (DAQ) stops recording during an experimental session; this precaution can help other researchers avoid problems of similar scope.

Table 2-2. Overview of Participants included in Analysis

Time of Data Collection	No. of Participants	No. of Participants with Attention Deficit Disorder	No. of Sessions with Data Collection	Total No. of Participants by Sessions	Male/Female by Session
Data Collection: Round 1 (Spring 2015)	19 (Male: 7; Female: 12)	7 (Medication: 2; TOVA: 5)	With Session 1 only	6	Male: 3
					Female: 3
			With Sessions 1 and 2	13	Male: 4
					Female: 9
Data Collection: Round 2 (Fall 2015)	27 (Male: 4; Female: 23)	6 (Medication: 1; TOVA: 5)	With Session 1 only	2	Male: 0
					Female: 2
			With Sessions 1 and 2	25	Male: 4
					Female: 21
Total(s)	46	13 (TOVA:10)			Male: 11
					Female: 35

DATA ANALYSIS

The measures of analysis used in this experiment were: (1) root mean square deviations (RMSD) of lateral lane position (also known as the standard deviation of lateral lane position), (2) RMSD of speed (or standard deviation of speed), (3) RMSD of speed from requested speed of 60 mph (accuracy error), (4) mean speed, (5) identification errors, and (6) detection time margins (DTM) for the performance task. Mixed-model Analyses of Variance (ANOVA) with attention deficit group membership as the between-subject factor and condition (event versus non-event segments) as the within-subject factor were used to analyze the speed, lane, and detection time metrics obtained (Table 3-1). Additional mixed-model ANOVAs, with the same between-subject factor but with event type (accident, billboard, no distraction, police cars, work zone) as the within-subject factor was executed to further examine performance differences between the distractor types (Table 3-2). Gender did not reach significance as a main effect and therefore was not included as a between-subjects factor in the analysis, an outcome consistent with findings in the literature (*44*). The Greenhouse-Geisser correction was used when assumptions of sphericity were violated, and Bonferroni adjustments were used for post hoc pairwise comparisons. There were some outliers present in the data, but these were not removed unless a systematic problem could be identified with the data or participant; this approach resulted in one participant (female) being removed from the response accuracy and latency analyses due to behavior that indicated misunderstanding of the instructions (i.e. responded to distractors rather than the diamonds). All statistical analyses were executed in IBM SPSS Statistics 22 ®.

Performance measures associated with the five roadway events were taken over 1.25 mile lengths of the roadway (.625 miles preceding and following the events), and the non-event sections were aggregated over the lengths of roadway between the 1.25-mile events' segments (see Figure 2-3). Non-event segment lengths varied due to the aforementioned random variation in placement of the events across the five unique scenarios. The final event (Event 5) was removed from all analyses, with the exception of the response accuracy and latency measures, to account for confounding speed and lane behavior that may have been associated with the impending end of scenario. The data from the two scenarios with and without lead vehicles were aggregated, as paired t-tests indicated no significant differences between these scenarios for the lane position, speed deviation, and detection time performance measures. Additionally, all participants drove a scenario with the lead vehicle and one without the lead vehicle in each session, and the order of these were counterbalanced across participants.

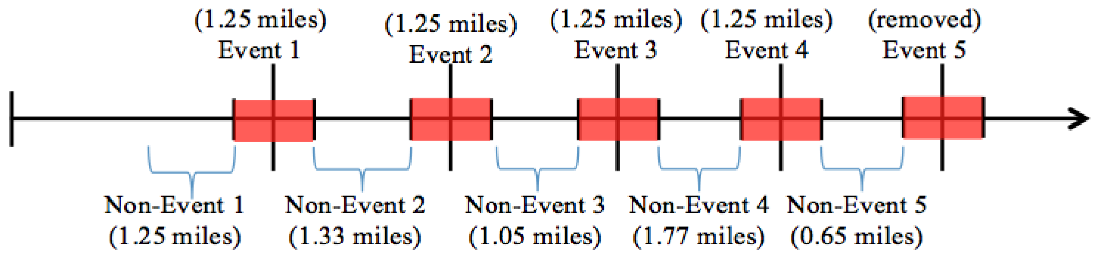

Figure 2-3. Sample Event and Non-Event Segments used for Analysis

CHAPTER 3. FINDINGS AND APPLICATIONS

Descriptive summaries of the performance measures and response latencies, as well as results from the statistical analyses are presented in Table 3-1 and Table 3-2. Identification errors for the simulator performance task are shown in Table 3-3.

ANALYSIS OF DRIVER PERFORMANCE METRICS FOR EVENT AND NON-EVENT SEGMENTS

A main effect of condition (event versus non-event segments) was found for the RMSD of lateral lane position ($F(1, 44) = 17.05$, $p < 0.001$), with post-hoc pairwise comparisons (Bonferroni corrected $\alpha = 0.025$) showing that the event segments of the drive had statistically significant larger standard deviations than the non-event segments of the drive. Group membership was also found to be a main effect on RMSD of lateral lane position ($F(1, 44) = 5.38$, $p = 0.03$), with drivers in the attention deficit group having statistically significant larger variability of lane position than drivers in the control group.

There were also main effects of condition for the RMSD of speed ($F(1, 44) = 8.19$, $p = 0.006$), as well as for the RMSD of speed from 60 mph ($F(1, 44) = 6.3$, $p = 0.02$). Again, pairwise comparisons indicated the event segments had statistically significant higher deviations for both of the speed fluctuation metrics relative to the non-event segments of the drive.

Although group membership did not have statistically significant effects on the RMSD measures of speed, examination of Table 3-1 shows that drivers in the attention deficit group did have increased speed fluctuations for both the event and non-event conditions, though the absolute magnitude of these impacts is small.

Finally, the results showed a statistically significant two-way interaction between group membership and mean speed for event versus non-event segments of the drive, $F(1,44) = 5.34$, $p = 0.03$), which was driven by the fact that drivers with attention deficit tendencies had increased speeds in the non-event portions of the drive relative to the event portions, a trend that was reversed for the control group drivers.

ANALYSIS OF DRIVER PERFORMANCE METRICS BY EVENT TYPES

Results from the second mixed-model ANOVAs indicated a main effect of group membership for the RMSD of lateral lane position across the five event types ($F(1, 44) = 4.71$, $p = 0.04$), with pairwise comparisons (Bonferroni corrected $\alpha = 0.025$) finding that drivers in the attention deficit group had greater standard deviations of lane position across event types. Group membership was not statistically significant for the other performance measures; however, examination of Table 3-2 reveals that drivers in the attention deficit group did have increased speed fluctuations across all five events, relative to the control group.

Although event type was only a marginally significant main effect ($F(2.29, 176) = 2.35$, $p = 0.09$), post-hoc comparisons (Bonferroni corrected $\alpha = 0.01$) found that there was a significant difference in RMSD of lateral lane position between the work zone and billboard events. Work zone events had statistically significant greater standard deviation of lane position than the billboard events. There were no other main or interaction effects found across the event type and group membership variables for the speed performance metrics.

Table 3-1. Summary Table of Performance Metrics for Event and Non-Event Conditions

	Mean (95% CI)				Main Effect of Within-Factor Variable (Condition) (α = 0.05)	Main Effect of Group Membership (α = 0.05)	Interaction Effect: Condition vs. Group Membership (α = 0.05)
Between Factor:	**Attention Deficit Group**		**Control Group**				
Within Factor:	**Non-Event Segments**	**Event Segments**	**Non-Event Segments**	**Event Segments**			
RMSD Lateral Lane Position (ft)	1.21 (0.16)	1.46 (0.26)	1.01 (0.09)	1.15 (0.14)	F(1, 44) = 17.05, p < 0.001	F(1, 44) = 5.38, p = 0.03	F(1, 44) = 1.6, p = 0.21
RMSD Speed (mph)	2.36 (0.80)	2.80 (0.96)	1.94 (0.42)	2.18 (0.51)	F(1, 44) = 8.19, p = 0.006	F(1, 44) = 1.17, p = 0.29	F(1, 44) = 0.69, p = 0.41
RMSD Speed (relative to 60 mph) (mph)	2.80 (1.03)	3.17 (1.06)	2.20 (0.54)	2.42 (0.56)	F(1, 44) = 6.3, p = 0.02	F(1, 44) = 1.38, p = 0.25	F(1, 44) = 0.39, p = 0.54
Mean Speed (mph)	60.50 (0.98)	60.08 (0.87)	60.07 (0.52)	60.18 (0.46)	F(1, 44) = 1.93, p = 0.17	F(1, 44) = 0.11, p = 0.75	F(1,44) = 5.34, p = 0.03

[1] Greenhouse Geisser Correction

Table 3-2. Summary Table of Performance Metrics for Event Types (n = 46 for each performance measure unless otherwise noted)

	Mean (95% CI)										Main Effect of Within-Factor Variable (Event Types) (α = 0.05)	Main Effect of Group Membership (α = 0.05)	Interaction Effect: Event Type * Group Membership
Between Factor:	**Attention Deficit Group**					**Control Group**							
Within Factor:	**AC**[1]	**BD**[1]	**ND**[1]	**PO**[1]	**WZ**[1]	**AC**[1]	**BD**[1]	**ND**[1]	**PO**[1]	**WZ**[1]			
RMSD Lateral Lane Position (ft)	1.50 (0.40)	1.12 (0.20)	1.24 (0.23)	1.42 (0.42)	1.33 (0.21)	1.10 (0.21)	0.96 (0.10)	1.01 (0.12)	1.07 (0.22)	1.14 (0.11)	[2]$F(2.29, 100.61) = 2.35$, $p = 0.09$	$F(1, 44) = 4.71$, $p = 0.04$	[2]$F(2.29, 100.61) = .552$, $p = 0.60$
RMSD Speed (mph)	2.37 (0.87)	2.39 (0.95)	2.14 (0.92)	2.28 (1.22)	2.33 (1.11)	1.66 (0.46)	1.29 (0.50)	1.79 (0.48)	1.85 (0.64)	2.10 (0.58)	[2]$F(3.21, 141.13) = .50$, $p = 0.70$	$F(1, 44) = 1.58$, $p = 0.22$	[2]$F(3.21, 141.13) = .79$, $p = 0.51$
RMSD Speed (relative to 60 mph) (mph)	2.79 (0.95)	3.07 (1.20)	2.60 (1.07)	3.25 (1.70)	2.81 (1.22)	2.08 (0.50)	1.72 (0.63)	2.23 (0.57)	2.63 (0.90)	2.63 (0.64)	[2]$F(2.95, 129.63) = 1.04$, $p = 0.38$	$F(1, 44) = 1.33$, $p = 0.26$	[2]$F(2.95, 129.63) = .89$, $p = 0.45$
Mean Speed (mph)	59.41 (0.91)	60.19 (1.15)	60.49 (1.04)	60.86 (1.70)	59.76 (1.12)	60.06 (0.48)	60.03 (0.60)	60.12 (0.55)	60.57 (0.90)	60.40 (0.59)	[2]$F(2.31, 101.54) = 1.95$, $p = 0.14$	$F(1, 44) = 0.04$, $p = 0.85$	[2]$F(2.31, 101.54) = 0.96$, $p = 0.40$
Detection Time Margin (seconds); *n = 30*	N/A[3]	1.63 (1.11)	2.45 (1.27)	1.65 (1.25)	1.79 (1.10)	N/A[3]	2.33 (0.57)	3.01 (0.64)	2.37 (0.68)	2.60 (0.60)	[2]$F(2.35, 65.89) = 5.18$, $p = 0.006$	$F(1, 28) = 1.26$, $p = 0.27$	[2]$F(2.35, 65.89) = 0.11$, $p = 0.92$

[1]AC: Accident Scene; BD: Billboard; ND: No Distraction; PO: Police; WZ: Work Zone
[2] Greenhouse Geisser Correction
[3] Accident scene did not have diamond marking, so response was not warranted

IDENTIFICATION ERRORS AND DETECTION TIME MARGINS FOR PERFORMANCE TASK

Identification Errors

Identification errors are missing responses at locations where a diamond was present and a response was expected (omission error), or responses made where no response was expected (commission error). Across all participants' data for session 1, there were a total of 17 omission errors made out of 460 (46 participants and 10 events) events. These errors were committed by approximately one third of the participants (Table 3-3). The miss rate per participant was slightly higher for the attention deficit participant group (0.40) relative to the control group (0.36) and similarly, the relative proportion of participants making an error was 0.40 for the former group relative to 0.31 for the latter. Of the 17 omission errors, nine occurred during the work zone event and six occurred during the police event. The remaining two errors occurred during the 'no distraction' and billboard events.

Table 3-3. Identification Errors during Performance Task

Classification	No. of Participants (No. Making Errors)	Errors	Average No. Misses Per Participant
Control	36 (11)	13*	0.36
TOVA (Attention Deficit Tendency)	10 (4)	4	0.40
Overall	46 (15)	17	0.37

*One participant made two commission errors at the accident scene, but this participant was removed from analysis because it is believed that the participant failed to understand the instructions.

Detection Time Margin (DTM)

DTM is defined as the length of time (seconds) between each participant's response and the diamond occurrence, and is inversely related to traditional reaction time; i.e. as reaction time decreases, DTM increases, meaning that the participant identified the diamond further in advance. For DTM, event type was a main effect ($F(2.35, 65.89) = 5.18$, $p = 0.006$) across participants. As shown in Table 3-2, participants in both the control and attention deficit groups responded with the longest DTM (measured in seconds) to the diamond that occurred in the presence of no distraction, and responded with the shortest DTM for the diamond occurrence in the vicinity of the billboard. Post-hoc pairwise comparisons (Bonferroni corrected $\alpha = 0.0125$) confirmed that the DTM differences between the billboard and no distraction events were statistically significant ($p = 0.007$). Similarly, the pairwise comparisons for DTM indicated that the no distraction event had statistically significantly greater DTM than for the police and work zone events ($p = 0.001$), meaning that participants responded significantly in advance of the roadway diamond when a distractor was not present in the environment. Although not statistically significant, participants in the attention deficit group also did consistently respond with a shorter DTM relative to the diamond occurrences than the control group participants, meaning that they had longer reaction times.

DISCUSSION OF FINDINGS

The authors believe that this is the first study examining the effects of roadside distractors on the performance of drivers with and without attention deficit tendencies (determined through TOVA). It is also among a small group of studies that has systematically examined roadside distractors for the general driving population. Primary findings from this study are discussed here, followed by limitations of this work.

There was a statistically significant main effect of condition (event versus non-event segments) on RMSD of lane position, RMSD of speed, and RMSD of speed from 60 mph across both driver groups. This finding indicates that drivers in this study had more variability in lane position and speed in the presence of roadside distractors relative to the segments of roadway without any distractors. However, the various types of distractors present did not result in any statistically significant differences in lane position or speed control, with the exception of lane position differences between the work zone and billboard distractors. As noted, there was also an interaction effect of group membership and condition on mean speed. Drivers with attention deficit tendencies had higher mean speeds in the non-event segments of the drive relative to the event portions of the drive, a trend that was reversed for control group drivers. The main effect of group membership on lane position is consistent with previous literature that reports drivers with attention deficit disorders have increased variability in lane position, irrespective of distractions (*38; 43*), although it should be noted that the cited literature primarily studied in-vehicle distractions. Conversely, group membership was not found to have significant effects on accuracy (RMSD from 60 mph) or precision errors (RMSD Speed) related to speed control in this experiment. There are differences in findings with regards to speed in the literature, with some studies reporting significant differences between groups (*43; 44*), and others finding no group differences in speed control (*42*).

Participants were required to respond to diamond pavement markings that were placed in the vicinity of roadside distractors in 80% of the cases (with the remainder of the pavement markings unaccompanied by distractors). A mixed-model ANOVA executed on DTM to these pavement markings found that drivers took the longest to respond to the markings in the vicinity of the billboard, and responded most in advance to the markings that did not have distractors. Analysis of the identification errors found that 33% of drivers (15 out of 46 participants) made a total of 17 omission errors, with 9 of these errors occurring in the work zone, and 6 occurring in the vicinity of the police cars. These findings may suggest that the work zone distractor was most likely to redirect visual attention away from the roadway for sustained lengths of time (i.e. a length of time sufficient for missing the marking), while the billboard redirected attention but did not prevent the participants from scanning the scene with enough time to complete the task. Also of note was the finding of significant differences in standard deviation of lane position between the billboard and work zone events, with the work zone events eliciting significantly higher standard deviations of lane position than the billboard events. No statistically significant effects of group membership were found for the DTM, although Table 3-2 does indicate that drivers with attention deficit tendencies responded when they were much closer to the diamond (shorter DTM) than drivers in the control group, thus indicating reduced performance. The identification error rate was only slightly higher (0.40) for the attention deficit group relative to the control group (0.36).

CHAPTER 4. LIMITATIONS, CONCLUSIONS, AND FUTURE WORK

LIMITATIONS OF STUDY

This research used a driving simulator, which although extensively used for studying driver performance (*46*), will always have limitations with regards to fidelity of the driving experience (*47; 48*). Secondly, the share of participants with untreated attention deficit disorders or tendencies was 21.7% of the total participant sample, which, although a common difficulty in studies relating to such disorders, does limit the generalizability of results. Future work should seek to replicate these results with a larger, and more evenly distributed sample. Finally, the TOVA was the only measure of ADHD used in this experiment; additional measures such as psychological assessments based on the DSM-IV would further improve the assessment of which participants definitively suffer from attention deficit disorders.

CONCLUSIONS

Results from this study further unravel the implications of roadside distractors on driver performance, and can be applied to inform the analysis of distracted driving crashes. Findings from the study may also inform design guidance, particularly at sites where external distraction has been found to be a contributing factor to crash rates. Overall, this experiment demonstrated that roadside events have statistically significant effects on lane position variability and speed fluctuations. Moreover, certain roadside distractors (such as work zones and billboards) were found to have a greater impact on driver inattention, evidenced through decreased detection time margins and increased error rates in this experiment. Drivers with attention deficit tendencies had statistically significant increases in variability for lane deviations relative to the control group, and while not significant also had reduced performance on the speed fluctuations and detection time metrics.

Whereas the effects of in-vehicle distractions on driver performance have been extensively studied, this research effort represents a unique approach to examining the effects of common roadside events on driver performance. The findings lend insight on the effects of roadside distractors along a monotonous roadway, and suggest that future simulated and field studies of external distractors on driver behavior and performance are warranted. Efforts should be made to further explore the practical significance of these results, particularly in relation to safety. Ultimately, it is imperative to continue to study and understand why errors occur in the roadway environment, as it rapidly transitions into an increasingly dynamic and complex shared system.

FUTURE WORK

Examining the influence of roadside distractors on varied facility types and within different environmental settings (ex. urban arterial and urban freeway) would allow for a more complete understanding of the roadway conditions and attributes that exacerbate poor driving performance in the presence of roadside distractors, but was prohibitive here due to cost, and time constraints associated with retaining a large group of participants across a multi-session experiment. Additionally, the authors suggest a field study should be conducted to validate the current results and improve applicability in the field. As roadway and in-vehicle environments become increasingly complex, continued research regarding factors that impact driver performance and increase the likelihood of distracted driving are critical to ensuring safe system design for all transportation system users.

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