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EVALUATING INTERACTIONS OF TASK RELEVANCE AND VISUAL ATTENTION IN DRIVER MULTITASKING

By

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EVALUATING INTERACTIONS OF TASK RELEVANCE AND VISUAL ATTENTION IN DRIVER MULTITASKING

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Use of cellular phones while driving, and safety implications thereof, has captured public and scientific interest. Previous research has shown that driver reactions and attention are impacted by cellular phone use. Generally, previous research studies have not focused on how visual attention and driver performance may interact. Strayer and colleagues found lower recognition for items present in the driving environment when drivers were using a cellular phone than when not using the phone; however, the tested items were not directly relevant to driving. Relevance to driving may have an impact on attention allocation. The current project used a medium-fidelity driving simulator to extend previous research in two ways: 1) how attention is allocated across driving-relevant and -irrelevant items in the environment was investigated, and 2) driving performance measures and eye movement measures were considered together rather than in isolation to better illustrate the impact of cellular phone distraction on driver behavior.

Results from driving performance measures replicated previous findings that vehicle control is negatively impacted by driver distraction. Interestingly, there were no interactions of relevance and distraction found, suggesting that participants responded to potential hazards similarly in driving-only and distraction conditions. In contrast to previous research, eye movement patterns (primarily measured by number of gazes) were impacted by distraction. Gaze patterns differed across relevance levels, with hazards receiving the most gazes, and signs receiving the fewest. The relative size of the critical items may have impacted gaze probability in this relatively undemanding driving environment. In contrast to the driving performance measures, the eye movement measures did show an interaction between distraction and relevance; thus, eye movements may be a more direct and more sensitive measure of driver attention. Recognition memory results were consistently near chance performance levels and did not reflect the patterns found in the eye movement or driving performance measures.

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TABLE OF CONTENTS

Page

CHAPTER

APPENDIX

LIST OF TABLES

TABLE Page

LIST OF FIGURES

FIGURE Page

CHAPTER I

INTRODUCTION

The ubiquitous use of cellular phones while driving, and the safety implications thereof, has captured public and scientific interest. Previous research has shown that driver reactions and attention are impacted by cellular phone use, and legislative action has been taken in some states to limit drivers' use of cellular phones (Governors Highway Safety Association, 2009). In most previous studies, researchers have focused on one aspect, such as controlling the vehicle or managing increased attentional demands; there has been less consideration for how visual attention and driver performance may interact. The current project was designed to extend previous research by considering driving performance measures and eye movement measures in combination, focusing on how attention is allocated across different aspects of the driving environment. An in-depth evaluation of the relationship between visual attention and driving performance may also provide a foundation for more effective interface designs in situations that require driver multitasking, including cellular phone-like conversations (e.g., emergency response and dispatch, military communications).

Many evaluations of driving performance involve more than what can be defined strictly as 'driving', that is, steering the vehicle in an intended direction and applying force to the accelerator and brake pedals until an intended location is reached. A driver may be following a colleague's car to an unfamiliar location, scanning an urban area for potential hazards, or discussing options for dinner in a cellular phone conversation; each situation requires shifting attention away from the ‘primary’ task of controlling the vehicle as the ‘secondary’ task requires attention and working memory resources. As a common example, a driver may be required to actively scan a busy intersection for potential hazards. A driver who is focused on his driving is likely to be more aware of his vehicle’s status than is a driver who attempts to monitor the intersection while having a conversation with a passenger (e.g., McEvoy, Stevenson, & Woodward, 2007). Additionally, some research indicates that a cellular phone conversation may be even more disruptive to a driver’s performance than is a conversation with a passenger (e.g., Strayer & Drews, 2007).

Personal experience tells us that most experienced drivers can manage a moderate level of multitasking and arrive safely at their destination. Nevertheless, research tells us that even a moderate level of multitasking negatively impacts driving performance. For instance, Stutts et al. (2005) recorded drivers’ behavior for a week and found increased incidences of drivers having their hands away from the steering wheel and unintended lane incursions when drivers were distracted from the driving task by other tasks. Another field study investigating the cellular phone usage of drivers involved in vehicle collisions (Redelmeier & Tibshirani, 1997) found a fourfold increase in relative risk for collisions when a cellular phone was in use by the driver; the greatest increase in relative risk of a vehicle collision was found when cellular phone calls were made within the five minutes just prior to the collision.

According to a report from the National Highway Traffic Safety Administration (NHTSA), approximately 11% of drivers were using hand-held devices (including cellular phones) while driving on an average day in 2008 (NHTSA, 2009); the same report indicated nearly 6,000 fatalities and over 500,000 injuries related to distracted and inattentive driving for the year. Although there is clearly a safety impact of using a cellular phone on driving, drivers still have relatively few collisions compared to the frequency of occurrence for the combined tasks. One would anticipate that drivers aim to selectively use their cellular phones when they perceive relatively undemanding driving conditions and avoid using their phones when demands are higher. There may also be subtle attentional factors that work to lower the practical impact of secondary tasks. For instance, drivers may selectively restrict their attention to more driving-relevant information (e.g., other vehicles, interchanges) at the expense of less relevant information (e.g., roadway advertisements, buildings along the roadway; Richard, Wright, Ee, Prime, Shimizu, & Vavrik, 2002) in addition to increasing the distance between their vehicle and others (e.g., Cooper & Strayer, 2008).

The current project investigated the impact of cellular phone conversation on visual attention during simulated driving, based on the relevance of objects in the driving environment. In addition to comparing driving performance while using a cellular phone to driving only, this project more closely integrated overt visual attention measures with driving performance measures in order to more directly evaluate the potential interactions between driver behavior and attention. Finally, this research provided an opportunity to validate a new driving simulator by comparing and contrasting the results with those from other driving simulation laboratories.

Literature Review

Salvucci (2006; Salvucci & Taatgen, 2008) posits that driving is a complex and multidimensional task, requiring the driver to monitor and control the current status of the vehicle. At the same time, the driver must navigate within a dynamic environment including other vehicles, various hazards, and changing weather conditions in order to perform the driving task safely. Unsurprising in a task as complex as driving, the addition of a secondary task (e.g., a cellular phone conversation) negatively impacts driver response on several levels (Alm & Nilsson, 1995; Reed & Green, 1999; Strayer & Johnston, 2001; Stutts et al., 2005). Hypotheses addressing why driver response is impaired vary substantially, from a general increase in mental workload (Alm & Nilsson) to ‘inattentional blindness’ as attention is withdrawn from the driving environment (Strayer & Johnston).

Researchers’ methods differ in their strengths and limitations, making it difficult to get a clear picture when comparing multiple studies, but there are some patterns that have emerged. The degree to which a driver’s goals diverge from the requirements of driving in support of a secondary task has been shown to impact situation awareness (Ma & Kaber, 2007) and vehicle control performance (Cnossen, Meijman, & Rothengatter, 2004; Stutts et al., 2005). Numerous researchers have presented findings that indicate that driving performance is affected by the addition of secondary tasks (e.g., Blanco, Biever, Gallagher, & Dingus, 2006; Reed & Green, 1999), but the effects are generally mild enough that driving performance generally remains within safe levels (Hancock, Simmons, Hashemi, Howarth, & Ranney, 1999; Pöysti, Rajalin, & Summala, 2005).

One potential reason for the higher accident risk found in field studies (e.g., Stutts et al., 2005) may be slower reaction times to quickly changing situations, as indicated by Hancock et al.'s (1999) results on a test track. More specifically, the presence of two tasks may compete for a central pool of resources, resulting in a 'bottleneck' (e.g., Levy & Pashler, 2008). Although drivers may drive more slowly in order to compensate for slower reactions, when an emergency situation occurs the additional compensation may not be enough to prevent a collision (Hancock et al.). Other researchers (e.g., Briem & Hedman, 1995; Cnossen et al., 2004) have also recorded instances where drivers apparently attempt to compensate for distraction resulting from multitasking. A meta-analysis by Caird, Willness, Steel, and Scialfa (2008) found that drivers sometimes attempted to compensate by increases in headway and decreases in speed; however, the meta-analysis results determined that drivers' compensation is generally not sufficient to completely mask the impact of driver distraction.

Most previous research projects have focused on one aspect of driver performance, such as driver response, attention, situation awareness, etc. For instance, Hancock and his colleagues (Hancock et al., 1999; Hancock, Lesch, & Simmons, 2003) focus on driver response at a practical level (i.e., braking response times). In contrast, Strayer and his colleagues (e.g., Strayer & Johnston, 2001) focus on visual attention in driving, considering driving performance measures only as necessary to ground their results in the applied domain. The current project combines aspects from two diverse research domains, driving performance research and visual attention, and aims to take a more balanced and integrative approach, requiring at least some background in both research domains. The following sections thus describe general relevant findings in each domain in turn, beginning with investigations of driving performance.

Driving Research – Instrumented Vehicles and Test Tracks

The history of driving research is long (e.g., Brown, Tickner, & Simmonds, 1969) with most early research occurring on improvised test tracks. Test tracks provide better control of the driving environment than is available on public roads, but they also exclude aspects of the driving environment such as traffic that may impact driver performance. Technical advances have allowed for vehicles to be instrumented so that measures can be collected while the participant drives on actual roads and highways (e.g., Recarte & Nunes, 2000; 2003), providing the clearest ecological validity. Recarte and Nunes (2000) used an instrumented vehicle to investigate the differential impact of spatial imagery and verbal memory tasks on driving performance, in order to better understand the impact of ‘internal’ distraction, compared to ‘external’ distractions such as in-vehicle devices. Vehicle monitoring via glances to the mirrors and dashboard were less frequent during spatial imagery tasks, indicating a withdrawal of attention from the driving task (see also Blanco et al., 2006). Further evidence from Recarte and Nunes (2003) indicated that both detection and identification of relevant aspects of the driving environment were negatively impacted by mental tasks while driving.

When using instrumented cars on actual roads, factors such as weather, road surface, traffic, and so on, cannot be controlled, and care must be taken by the researchers to balance these factors as evenly as possible across the conditions to avoid potential confounding. Additionally, when researchers are interested in response to unexpected, or critical, events, test tracks are viewed as the better approach, supporting a middle ground between simulation and actual roadways (Hancock et al., 1999; Hancock et al., 2003). Hancock et al. (1999) tested participants' responses to a signal for an immediate stop while also performing a cellular phone-like working memory task. Interestingly, Hancock et al. found that stopping distances were actually shorter at higher speeds, as participants compensated by braking harder. A similar effect for both stopping distance and braking rate was found comparing the driving-while-distracted trials to driving alone. That is, drivers would brake harder, resulting in a shorter stopping distance when driving while distracted; the harder braking seemed to be compensation for a delayed response. Even with the higher braking rate, participants' stopping distances still indicated a 24% decrease in the 'safety margin' (i.e., the distance between the vehicle and the end of the braking area), suggesting that although participants were aware of a negative impact on their performance, the compensations were not entirely effective.

Instrumented vehicles and test track research have provided several insights into driver performance, some of which have been described here. However, there are ethical and safety limits to what an experimenter can do when using real vehicles on real roadways, including test tracks. Drivers participating in experiments are bound to abide by the same rules as everyday drivers; an experiment cannot investigate aspects of driving performance that may endanger participants or bystanders (e.g., high speeds, response to tire failures, driver intoxication, etc.). Investigation of high-risk driving scenarios requires other methods, including epidemiological studies, detailed accident reconstruction and driving simulation.

Driving Simulation

In order to investigate aspects of emergency response, imminent collisions, and other potentially hazardous situations, experimenters often opt to use driving simulation. Equally important, the use of driving simulation gives researchers the ability to control weather, traffic, and other environmental conditions that can complicate analyses of driver performance in naturalistic driving. In general, driving simulation allows for greater experimental and scenario control than is available in actual vehicles. Driving simulators vary widely in their ‘fidelity’, that is, in how closely they mimic the actual driving experience. Vehicle controls may range from a desktop computer and joystick to an intact vehicle cab. Some may provide only a limited field of view whereas others may incorporate large cylindrical or dome screens to provide an immersive environment. Many driving simulators provide only visual and auditory feedback, but there are others that also incorporate motion cues, vibration, and subtle nuances of vehicle dynamics. Indeed, driving simulation can be used to evaluate vehicle design aspects ranging from interface design to chassis and suspension configurations.

Of greatest importance here, simulation can be used to investigate participant behavior in situations that would be dangerous and/or unethical in actual driving environments. In an effort to validate the use of simulation in comparison to actual driving, several simulated driving tasks have shown similar patterns to those indicated in actual driving situations (e.g., Stutts et al., 2005). One concern is whether participants ‘drive’ more recklessly in simulated environments where there are no safety consequences. Lateral position in the driving lane has been found to be more variable in simulated driving than on actual roadways (Blaauw, 1982; Blana & Golias, 2002), in part due to less realistic feedback from the ‘vehicle’. Some researchers (Kaptein, Theewes, & van der Horst, 1996; Mourant, Jaeger, & Lin, 2007) have similarly found increased speed variability in simulated driving. Potential differences in how people drive in simulated and actual environments may obscure or complicate generalizations of research findings.

The general consensus is that driving simulation often provides good ‘relative’ validity, resulting in similar patterns of data as those found in actual driving, even when absolute validity (i.e., precise matching of values, deviations, etc.) may be lacking (Blaauw, 1982; Kaptein et al., 1996). Participants given instructions to “drive normally” generally seem to appropriately classify the driving task as of primary importance, as one would expect on a standard roadway (e.g., Lee, Caven, Haake, & Brown, 2001). Not surprisingly, simulation fidelity (i.e., how realistic a simulation experience is, including motion cues, field of view, etc.) impacts driver experience (McLane & Wierwille, 1975; Mourant et al., 2007). For example, Allen, Park, Cook, & Fiorentino (2007) found that participants trained in a medium-fidelity simulator with a wide view angle and a vehicle cab had an subsequent (real-world) accident rate only one-third of that estimated for the general population; other configurations were less effective, and a single-monitor, low-fidelity system led to no differences between the participants’ accident rate and the general population.

Multitasking Research in Driving Simulators

Assuming that simulated driving replicates the most important features of standard driving situations, research in driver multitasking has brought to light several safety concerns. Briem and Hedman (1995) found that manipulation of a cellular phone or a radio impacted vehicle control, particularly when managing more difficult (i.e., slippery) road surfaces. The same researchers also found that participating in a demanding conversation negatively impacted vehicle control regardless of the simulated road surface condition. (See Strayer & Drews, 2007, for contrasts between conversations with a passenger and over a cellular phone.) Using simulation to evaluate a speech-based e-mail system, Lee et al. (2001) found delays in braking in reaction to a critical event, similar to the results of Hancock et al. (2003); complexity of the driving environment also seemed to impact response time, suggesting that delays in braking response could be even longer in complex (e.g., urban, high traffic) environments than in test track and simpler simulated environments.

The theoretical heart of deficits in individual task performance when multitasking is attention and its allocation across tasks. Visual attention is particularly important to a driver maintaining control of a vehicle (Hole, 2007), leading to expectations that tasks such as conversing on a hands-free cellular phone device should not substantially impact driving performance, as it is a primarily auditory task and the manual demands of manipulating the phone and holding it to one’s ear are minimized. However, research has indicated that even apparently compatible tasks (i.e., tasks that require different types of perceptual and attentional resources) can interfere with one another (Blanco et al., 2006;

Levy, Pashler & Boer, 2006). Additionally, the relative effect size of distraction and multitasking deficits in simulation studies is often similar to that of naturalistic research (Caird et al., 2008) leading to the general conclusion that driver multitasking, of which using a cellular phone while driving is one example, is attentionally demanding and results in a common form of driver distraction.

Driving simulation studies have also indicated the presence of interactions between driving and different types of secondary tasks. Cnossen et al. (2004) found that the relevance of information gained from the secondary task impacted drivers' allocation of attention between the primary and secondary tasks. (See Richard et al., 2002, for additional evidence of strategic attention allocation.) More specifically, drivers would ignore a 'driving-irrelevant' working memory task to focus on maintaining their driving performance. However, drivers continued to attend to the map, even when it resulted in less steering control (i.e., more swerving; Cnossen et al.).

Although the relative relevance to driving of a map-reading task versus a working memory task seems clear, it is more difficult to determine the potential for relevance interactions in a cellular phone tasks, in which the context can vary greatly across conversations. Despite this potential limitation and in line with Redelmeier and Tibshirani's (1997) observations, David Strayer and colleagues (Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001) have found that naturalistic cellular phone conversations negatively impacted driver attention to the driving task, suggesting that drivers are attempting to divide their limited attentional resources between the two demanding tasks. As an explanation for resulting driver performance deficits, Strayer posits an *inattentional blindness* interpretation, based on eye movement recordings, recognition performance (Strayer et al.), and driver behavior (Strayer & Drews, 2007).

Inattentional Blindness in Driving

Inattentional blindness refers to an inability to perceive an unexpected object, even when it occurs in a clearly visible, and perhaps even fixated, location (Most, Simons, Scholl, Jimenez, Clifford, & Chabris, 2001). The underlying source of inattentional blindness is believed to be that although the eyes are fixated at one location, attention is being directed to a different location (Koivisto & Revonsuo, 2007). In a typical inattentional blindness study, participants are asked to view a display and do a simple task (e.g., identify the longer arm of a presented cross; Mack & Rock, 1998). Although the actual number of trials may differ, there are three trials of particular interest: During a *critical trial*, an unexpected object appears at some location in the display; after the trial, participants are asked whether they noticed anything unusual during the trial. The same process is repeated, referred to as a *divided attention trial* because participants have been primed to expect something unusual by the questions following the critical trial. Finally, participants are told to only view the display and describe what they see in a *full attention* (or *control*) trial that provides a baseline for comparison to performance in the critical and divided attention trials. In the case of the critical trials, a large percentage of participants do not see the unexpected stimulus; stimulus characteristics impact the likelihood of detection, so that detection rates may vary from 10% detecting it (e.g., when it has similar characteristics to distractors) compared to 10% missing it (e.g., when it is similar to the target; Most, Scholl, Clifford,

& Simons, 2005). The percentage of participants noticing the unexpected object increases in the divided attention trials. For both the critical and divided attention trials, the detection rates are compared to those in the full attention trial, as performance in this trial is used both as a baseline for performance and an exclusion criterion (i.e., if participants did not report detecting the unexpected object in the full attention trial, their data for the other trials was not analyzed further).

Traditionally, inattentional blindness research has involved relatively simple displays in which participants viewed a number of moving objects while maintaining a central fixation and shifting attention covertly (Mack & Rock, 1998; Most et al., 2001). However, similar results have been obtained when participants were able to move their eyes freely across the display (Bressan & Pizzighello, 2008), and Strayer and colleagues (Strayer & Drews, 2007; Strayer et al., 2003; Strayer & Johnston, 2001), among others, have extended the paradigm to driving situations.

As an initial analog to driving, Strayer & Johnston (2001) described research using a pursuit tracking task, in which participants tried to keep a cursor over a moving point using a joystick. Traffic signals were simulated in the tracking environment to more strongly relate to driver steering behavior. The tracking task was combined with secondary auditory tasks to investigate the basic properties of talking on a cellular phone while driving in a simplified experimental context. Participants listened to a book on tape or the radio, shadowed (i.e., repeated) a word list, or generated new words in response to a word list. Only the word generation task impacted pursuit tracking performance; it appears that the shadowing and listening tasks were not overly demanding of attentional resources. Additionally, when conversing over a handheld cellular phone was compared with a hands-free phone in another experiment, there was no difference in performance; both cellular phone conditions resulted in more missed traffic signals (i.e., inattentional blindness) and slower reactions compared to driving only, suggesting the importance of attentional factors over manual factors in maintaining tracking performance.

The pursuit tracking task used in Strayer and Johnston (2001) was used for improved experimental control, but the results parallel others found in more ecologically valid driving environments. In an instrumented car, Recarte and Nunes (2003) found that both detection and identification of a visual stimulus was negatively impacted by a production task but not by a less demanding information acquisition/maintenance task. In a follow-up study to Strayer and Johnston, Strayer et al. (2003) presented a series of experiments, most of which were conducted in a fixed-based driving simulator. Of primary interest are their Experiments 2 and 3, in which participants used a hands-free cellular phone while driving as they normally would on a standard road. Participants drove through a simulated environment in six scenarios; half of the time (i.e., three scenarios, grouped together as a single block), they were also engaged in a conversation with an experimenter.

In both Experiments 2 and 3, Strayer et al. (2003) had participants complete a surprise recognition test for billboards that were presented during the drives. In Experiment 2, the memory results indicated a 47% decrease in memory performance for billboards presented during the cellular phone scenarios. Experiment 3 added eye movement recording to the design of Experiment 2, indicating that participants fixated the billboards at similar rates, ruling out a strictly eye movement-based explanation. Replicating the results of Experiment 2, recognition performance was again significantly lower during cellular phone conversations than during the control drives. Thus, participants exhibited inattentional blindness for billboards that they viewed during the driving task; Strayer et al. concluded that as attention is withdrawn from the driving environment by the cellular phone task, this withdrawal contributes to the increased accident risk reported by Redelmeier and Tibshirani (1997) and others.

Impact of Driving Relevance on Attention Allocation

One question left unresolved by Strayer et al.'s (2003) results is how attention to objects such as billboards might differ from driving-relevant objects such as pedestrians, other vehicles, and other potential hazards. Previous research (e.g., Hayhoe, 2000) has found eye movements generally conform to the specific task, with few fixations to irrelevant locations. Crundall, Van Loon, and Underwood (2006) found that the street-level advertisements were fixated more often than the raised advertisements when participants were asked to rate hazards; however, participants scored lower for street-level advertisements than for raised advertisements on a recognition test. Crundall et al. argued that street-level advertisements may pull or 'capture' attention from the hazard perception task (perhaps in a similar manner to Strayer et al.'s hypothesis with cellular phone conversations), directing resources away from the hazard perception task, which is an integral part of driving. It is possible that drivers had to actively switch their attention between the raised advertisements and the driving environment, whereas they may have (whether implicitly or explicitly) attempted to divide attention between the driving environment and the street-level advertisements, resulting in less attentional resources allocated to processing of the street-level advertisements despite more visual processing time.

Other research has shown that the relationship between the primary driving task and secondary task may impact secondary task performance. Cnossen et al. (2004) found that participants' performance on a working memory task suffered more than their performance on a route guidance (i.e., map reading) task. In contrast, driving performance suffered more when paired with the route guidance task than with the working memory task, suggesting that drivers attended more to the secondary task they deemed more relevant to the primary driving task. In a driving-related change blindness study, Richard et al. (2002) used an image-flicker task to evaluate the impact of an object's relevance to driving on ability to detect changes in a driving scene; the addition of an auditory task slowed detection performance overall, but the effect was larger for driving-irrelevant objects (e.g., a mailbox) than for driving-relevant objects (e.g., a traffic light).

The current project extends Strayer et al.'s (2003) Experiment 3 to examine the impact of an object's relevance to driving on subsequent recognition memory. As in Strayer et al., the current study compared driving, eye movements, and memory performance while participants were and were not using a cellular phone. Each driving scenario included billboards, but each scenario also included potentially hazardous situations and driving-relevant signs. After completion of the driving scenarios, the participants were asked to complete an old/new recognition test for both driving-irrelevant (i.e., billboards) and driving-relevant (i.e., signs, hazards) objects in the environment.

Research Goals

The current research aims to determine the impact of relevance to the driving task on memory for events in the driving environment. Additionally, the current research more tightly integrates driving performance and eye movements than has been done previously. For instance, even when drivers' memory performance may indicate that they do not recall a certain hazard, the driving performance measures may indicate that they did in fact respond to the hazard, by slowing down, shifting their lane position away, and so on. Being able to more clearly link driving performance and visual attention may illuminate less obvious aspects of the interactions between attention and driver behavior. Thus, although drivers show impaired memory, and presumably awareness, for events that occur in the driving environment while using a cellular phone, they may still be capable of monitoring and responding to certain (i.e., driving-relevant) events in the driving environment at some level.

Hypotheses Regarding the Impact of Cellular Phone Use on Driving Performance

There are several aspects of potential interest when considering the impact of cellular phone use on driving performance. The current research aims to both replicate previous results and extend them by analyzing eye movement patterns directly in conjunction with driving performance measures. My intention is that the end result of the current project provides a more coherent and complete account of how the attentional demands inherent in cellular phone use impact driver performance.

Hypothesis #1: Driving performance measures will indicate reduced vehicle control during the secondary cellular phone task. In particular, speed control will be more variable (Horrey & Wickens, 2004). Steering may also be more variable (Cnossen et al., 2004; Reed & Green, 1999). Variability in both speed and steering control may indicate greater attentional demands on the driver in order to accommodate both driving and the cellular phone tasks. The primary aim for this hypothesis is to validate the use of the driving simulator in driver multitasking research and to provide a foundation for comparisons between this project and other simulation research.

Hypothesis #2: Driving performance measures will indicate that hazards are not detected as effectively when participants are performing the secondary task as when they performed only the driving task. More specifically, braking responses will be slower and more braking pressure will be applied, similar to the test track results of Hancock et al., 1999.

Hypothesis #3: Eye movement patterns will not differ between the driving-only and distraction conditions, based on Strayer et al., (2003), providing evidence against a gaze-dependent explanation for any memory differences between the driving-only and distraction conditions. Strayer et al. reported an effect size of $d = 0.16$ for gaze probability and $d = 0.23$ for gaze duration; thus, eye movement patterns were expected to make only a small contribution to performance differences. Based on these previous results, I expect a null result as a formal (if unorthodox) hypothesis in an attempt to validate the assertion by Strayer et al. that the influence of differences in eye movement patterns is insufficient to explain distraction effects on driver performance.

Hypothesis #4: Regardless of whether a distracting task is being performed, participants will look at (i.e., fixate on) hazards more frequently than at billboards, based on their task relevance and central proximity in the driving environment, extending Richard et al.'s (2002) results to an interactive driving environment. Driving-relevant objects will likely be intermediate to hazards and billboards in the number and duration of gazes.

In their study, Richard et al. (2002) were able to rule out a central proximity-only explanation for differences in response times by relevance condition by analyzing gazes that occurred only in the central portion of the display; changes to driving-relevant objects were still detected more quickly than changes to irrelevant objects. A similar analysis will be necessary in the proposed study comparing the two relevance conditions based on the number and duration of gazes that occur on an object while it is located in the central section of the visual field, perhaps defined as on the driving simulator's center screen.

Hypotheses Regarding the Occurrence of Inattentional Blindness

Hypothesis #5: Eye movement results will reflect that participants 'looked at' the relevant environmental objects (i.e., hazards and billboards; see also Hypothesis #3), but the memory task results will indicate a lack of attention and recognition of fixated items in the distraction condition compared to the driving-only condition. An interaction based on objects' driving relevance may also be apparent (see Hypothesis #6).

Hypothesis #6: Whether memory differs for task-relevant hazards and task-irrelevant billboards remains an open question. For this reason, Hypothesis #6 is not a formal hypothesis; instead it is more accurately a stated research question. Taking into account this caveat, some predictions can be made. If relevance to the task impacts the occurrence of inattentional blindness, then memory for hazards should be higher than that for the billboards. Conversely, memory performance for the two classes of objects will be equal if task relevance does not impact the occurrence of inattentional blindness. Previous research by Most et al. (2001, 2005) has found that similarity to an attended versus an ignored stimulus set can impact detection in an inattentional blindness paradigm. Combined with results that suggest that relevant information is attended more frequently in a driving task (e.g., Cnossen et al., 2004), it can be expected that recognition will be better for hazards than for billboards; driving-relevant items may be intermediate, with higher recognition scores than billboards but lower than hazards. These expectations align with the predictions in Hypothesis #3, considering gaze duration and driving relevance; previous research (e.g., Hollingworth, 2005) in visual memory has found that participants are able to recognize scenes that they viewed previously at above-chance levels hours or even days later. Differences in memory performance across relevance are thus more likely to be due to differences in attentional processing rather than general memory decay, since long-term scene memory has been shown to be robust at the time intervals being considered here (Hollingworth, 2004; 2005).

Hypothesis #7: The combination of recorded eye movements and driving performance will indicate that participants responded to potential hazards (by looking at them, slowing down, steering away from the hazard, etc.), even when memory test results indicate a lack of attention. That is, by considering general trends across multiple measures, the impact of distraction on general trends in driver response to potential hazards in the environment can be investigated, and specific performance aspects that may be more sensitive than others to driver distraction may become apparent.

CHAPTER II

METHOD

Participants

Twenty licensed drivers from the Mississippi State University and local area population were paid $20 for their participation ($10 per hour for a maximum of 2 hours). This number was based on Strayer et al.'s (2003) Experiments 2 and 3 and the accompanying effect sizes. Two additional participants completed the familiarization drive, but were lost due to technical issues with the eye tracker.

Apparatus and Materials

The driving simulator at the Center for Advanced Vehicular Systems (CAVS) includes a Nissan Maxima cab mounted on a six degree-of-freedom hexapod motion base (see Figure 1). The actual vehicle controls used were the steering wheel, accelerator and brake pedals, and gear shift. The simulation vehicle dynamics model is based on a mid-sized sedan with an automatic transmission. Three large screens provide approximately 180 degrees of visual angle to the front of the vehicle, and two built-in LCDs (side mirrors) and another screen placed behind the simulator provide an immersive virtual environment for driving scenarios. The vehicle dynamics model and data collection capabilities were provided by Realtime Technologies, Inc., and are customizable using SimCreator 2.30. Due to limitations in the integration of the eye tracker with the simulator, the motion base functionality was not used for the current project. Communication between the experimenters and the participant occurred via an intercom system; the same system was used to simulate the hands-free cellular phone in the distraction condition.

Figure 1. CAVS driving simulator.

Scenario development was completed using SimVista, a tile-based environment set for Internet Scene Assembler Pro 2.0 and supported by JavaScript-based scripting to define behavior of agents (e.g., pedestrians, vehicles). SimVista supports both time-based and proximity sensors for triggering events in the driving environment, and there are several options for both weather and lighting effects. Provided graphical elements can also be supplemented with specialized textures and elements, producing highly customizable driving environments. For the current project, the scenarios were stretches of four-lane highway, divided into three straight sections of approximately 2000m each and connected by high-speed curves. The overall drive length was approximately 7000m and took roughly six minutes to complete. In addition to the static signs, hazards, and billboards used as stimuli, there was also light ambient traffic traveling the road with the simulated vehicle. The scenarios themselves were suburban areas transitioning from primarily residential to primarily commercial buildings or vice-versa. Screenshots from the scenario scenes were used in a recognition test, developed using EPrime 1.1 (Schneider, Eschman, & Zuccolotto, 2002a, 2002b). There were four driving environments overall: two versions of each of the two separate drives. Between the two versions of each drive, critical objects were swapped out to create a counterbalanced set of stimuli and foils. Objects that were present in one version of the drive served as foils for the other version. These screenshots were taken from the driver's point of view in the right-most lane, to most closely reflect positions from which the participants would view the objects. The screenshots were then cropped to show only the critical object and closely surrounding context.

Eye movements were recorded using a video-based, dash-mounted eye tracking system (faceLAB 4.6). An infrared (IR) light source is mounted between the two cameras, allowing for precision tracking of the eye via the relationship between the pupil and the reflection of the IR light on the cornea. Because the faceLAB system is dash-mounted, it is less obtrusive and fatigue-inducing than head-mounted systems. The faceLAB system has a sampling rate of 60Hz, and precision within approximately 0.5 degrees (°) of visual angle (~1° at the periphery). In its current configuration, the faceLAB system can accommodate approximately 30° of viewing angle, allowing the participant some freedom of movement in the scene. Additionally, the faceLAB system can make less precise estimates outside the viewing angle (e.g., glances to a side mirror), primarily based on head movement.

In addition to the driving scenarios, four questionnaires were also used in the current project. The first was the combined Motion Sickness/Simulator Sickness Questionnaire (MS/SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993). The MS/SSQ was completed before participants enter the simulator as a baseline, and subsequently after each driving task to screen for potential simulator sickness symptoms. The second questionnaire requested information on topics of interest to the participants in order to provide a basis for the cellular phone conversations. Potential topics of discussion included college and professional sports, politics, current events, and entertainment. The third questionnaire was the driving behavior questionnaire (DBQ) adapted by Reimer and colleagues for American drivers (see Reimer et al., 2005, for the full questionnaire). The items on the DBQ are geared toward various types of driver errors (failures of planned actions), lapses (attention and memory failures that may cause embarrassment), and violations (intentional practices that may be hazardous). Responses are given on a 0 to 5 scale (0 = never, 5 = nearly all the time). The fourth questionnaire requested basic demographic information, usage of in-vehicle technology, and experience with virtual/simulation environments (including video games). The questionnaires specifically designed for the current project (the interest questionnaire and the demographic questionnaire) are presented in Appendix B.

Experimental Design

Table 1 details the experimental design. Each participant completed two experiment drives, each containing three scenarios, which are defined as a straight section of road; high-speed curves separated the scenarios without disrupting the participant's experience of a single drive. Participants drove while having a casual conversation with an experimenter over a speaker/intercom system (to simulate hands-free driving, as with an integrated Bluetooth® system) for one blocked drive of scenarios and drove without a distracting task for the second blocked drive; the order of the drives were counterbalanced across participants. The scenarios were indistinguishable to the participant from the general driving environment; the participant experienced each drive as a single simulation run.

Table 1

Experimental Design – Independent Variables

Variable	# Levels	Levels
Scenario Condition	2	Phone Present/Phone Absent
Scenario Repetition	3	Scenario 1, Scenario 2, Scenario 3
Object Relevance	3	Hazard, Sign, Billboard
Object Repetition	2	Object 1, Object 2

As participants completed each experiment drive, they passed multiple critical objects at various points in each scenario. Critical objects were of three types: billboards, signs, or hazards. Replicating Strayer et al. (2003), billboards were used as 'driving-irrelevant' objects. Additional environment objects were classified as signs or hazards. Road signs were used as driving-relevant objects. Hazards included stalled and/or parked vehicles on the road shoulder and vehicles preparing to enter the roadway from side roads or driveways. Each scenario included two billboards (driving-irrelevant objects), two road signs (driving-relevant objects) and two potential hazards/events (hazard objects), resulting in six hazards, six signs, and six billboards per drive. These items provided the critical objects of interest for the recognition test. Additional objects (primarily buildings) and light traffic were also added to make the environments feel more realistic and less sparse.

As previously described, each participant passed critical objects while they completed each of the two drives: 'Driving Only' and 'Driving w/ Phone'. During the 'Driving w/ Phone' drive, each participant discussed a topic indicated as of interest to them with an experimenter. Conversations were initiated before the beginning of the first scenario and continued throughout the drive; there was no manipulation of the simulated hands-free 'phone' necessary at any point during the drive. The 'Driving Only' drive provided a baseline for driving performance measures. Driving performance measures included mean speed, variability of speed, braking pressure, mean lane position, and steering reversals. Eye tracking measures included number of gazes and mean gaze duration. More detailed descriptions of each driving performance and eye tracking measure is provided in Table 2. The faceLAB system (eye tracker) and SimCreator (driving simulator) data sets were synchronized with video recorded by SimObserver. The integrated video and data files were then processed using Data Distillery 1.3, which supports frame-by-frame analysis and annotation of synchronized data files and video. More specific information about how the video and data files were processed is presented following the Procedure description.

Table 2

Experimental Design – Dependent Measures

	Description
Driving Performance	
Mean Speed	Mean speed across each scenario
Variability in Speed	Standard deviation for speed across each scenario
Mean Braking Pressure	Mean pressure applied to brake pedal
Mean Lane Position	Mean absolute value of distance from center of lane
Variability in Lane Position	Standard deviation in distance from center of lane
Mean Steering Angle	Mean in steering wheel angle
Variability in Steering Angle	Standard deviation for steering angle across each scenario
Eye Movements	
Number of Gazes	How many times an object is fixated
Mean Gaze Duration	Mean time an object is fixated, in milliseconds
Memory Performance	
Recognition Accuracy	Number of images correctly identified

In order to test participant memory after completion of the experiment drives, a recognition test was developed. Two versions of a recognition test were used. Initial participants ($N = 5$) saw 72 images one at a time, presented in a random order. Of the presented images, 36 were from the driving scenarios (12 potential hazards, 12 signs, and 12 billboards), whereas the other 36 were new images (foils). Foils were included to provide an estimate for guessing. Participants indicated by a button press whether each image was from the presented driving environment ("old") or not ("new"). The remaining participants completed a two-alternative forced-choice recognition test that presented each of the 36 images from the driving scenes with their respective foils; participants then indicated which image, "left" or "right", corresponded with the driving scene. In both cases, presented images and foils were counterbalanced across participants and provided with visual context available around the object. Half the participants saw one set of objects in the driving environments, with the other set acting as foils, whereas the sets were swapped for the other half of the participants.

Procedure

The experiment was completed in a single session lasting a maximum of 2 hours (actual session duration was 1-1.5 hours). After providing consent to participate, each participant completed two questionnaires: the MS/SSQ and the interest questionnaire (see Appendix B). Each participant was seated in the simulator, shown the simulator controls, and completed a brief familiarization drive (approx. 5 min.). Participants were given time to drive freely during the familiarization drive, in order to acclimate to the vehicle controls and the simulated environment. Another MS/SSQ was completed immediately following the familiarization drive, after completing the first experiment drive, and finally after completing the second experiment drive. Each subsequent MS/SSQ score was compared to the initial, baseline score in order to screen for developing simulator sickness symptoms. No participants withdrew from the experiment due to simulator sickness, or for any other reason. The eye tracker was not used during the familiarization drive. After completion of the familiarization drive and simulator sickness screening (i.e., comparing the responses on first and second MS/SSQ), the eye tracker was calibrated; eye tracker calibration immediately preceded the first experiment drive. Once the eye tracker calibration has been completed, participants started the first of two experiment drives. Participants encountered multiple critical objects during each experiment drive. Participants completed the DBQ after completing the MS/SSQ following the first drive and just prior to recalibration of the eye tracker for the second drive. After participants completed both experiment drives, they were asked to complete a recognition test for critical objects in the scene. Finally, participants completed a demographic questionnaire (see Appendix B), were paid for their participation, and were debriefed on the purpose of the experiment.

Eye Movements and Combined Analyses

Eye movement information from the FaceLAB software was overlaid onto the video from the front screen of the driving simulator using a hardware genulock/overlay box (CorioGen Eclipse CS-450, TVOne). Two raters independently reviewed the videos in Data Distillery to determine 1) periods of time in which billboards, signs, and hazards were visible to participants, 2) the occurrence of gazes on critical objects, and 3) segments of straight-line driving, defining each scenario within a drive. Periods of availability of critical objects and segments of straight-line driving were defined as the midpoint between the two raters' reviews, due to limitations in playback video quality. The minimum number of samples for a 'gaze' to be counted was three video frames, roughly equivalent to 100ms. Initial match between raters averaged 0.94 (0.03 *SD*), sample-to-sample, with a 'worst-case' match averaging 0.82 (0.05 *SD*), referring to 1) marking all samples between the two ratings for the visibility window for each critical object, and 2) counting gazes only if both raters agreed. Once finalized, the Data Distillery files including integrated eye movement, driving, and critical object information were exported and entered into SAS 9.2 for aggregation and further analysis.

CHAPTER III

RESULTS

Of the twenty participants who completed the current study, experimenter error resulted in one participant only having overall driver performance data. An additional participant was lost from the eye movement analyses due to eye tracking equipment error. Therefore, the following analyses include data from twenty participants for the overall driving performance and memory analyses, nineteen for analyses on the individual driving scenarios, and eighteen for the eye tracking and combined analyses. In case of violations of sphericity, Greenhouse-Geisser corrections were applied to p values for repeated measures analyses if needed. Measures of effect size are provided through the use of Cohen's d for t-tests and eta-squared (η^2) for analyses of variance. Standards for the size of Cohen's d include $d = 0.2$ for small effects, $d = 0.5$ for medium effects, and $d = 0.8$ for large effects. Standard values for η^2 are less clearly defined, as it is a measure of the strength of association rather than an estimate of the degree of difference between groups; a larger η^2 value indicates a stronger association between the independent variable and the dependent measure being considered.

In addition, note that all of the following analyses include 'drive' as a between-subject variable. Although the design is a within-subject design, it is not a complete factorial; that is, participants either completed the driving-only condition as their first drive or their second drive, which is indicated by the 'drive' measure. It may be beneficial to consider the ‘drive’ variable as an indication of the order in which the two conditions were completed: either the driving-only followed by the distraction condition or the distraction condition followed by the driving-only condition.

Demographics of Participants

Twenty (12 male, 8 female) licensed drivers participated in the current project; participants averaged 24.4 years of age (*SD* =, 6.3) with a range of 18 to 42 years of age. Participants had been driving for an average of 6.8 years (*SD* = 7.0), and had on average 16.6 years of education (*SD* = 2.3). All participants owned a cellular phone, and 75% of them indicated that they used their phone while driving. Eighty percent of the participants indicated that they played video games, a common form of virtual reality or simulation technology.

Participants were also asked about their driving behaviors using the DBQ (Reimer et al., 2005). Three types of behavior were queried: errors (i.e., a behavior leading to an unintentional result or failure of a planned action), lapses (i.e., failures of attention or memory), and violations (i.e., an intentional and potentially hazardous act that conflicts with standard driver protocol or law). In general, the behaviors queried in the DBQ were rarely reported; there was one missing value due to a participant’s lack of response to a single question. Across all twenty-four questions, responses averaged 0.94 (‘rarely’), with a standard deviation of 0.97. Averages for each of the questionnaire subscales were also calculated. Participants averaged a response of 0.71 (*SD* = 1.10) for errors, a response of 1.06 (*SD* = 1.08) for lapses, and a response of 1.08 (*SD* = 1.31) for violations. The most common behavior indicated by participants was becoming impatient with a slow driver in the left-hand lane (average = 2.25, or ‘occasionally’), a violation of expected driving procedure. The least common behavior was hitting something they had not seen there while backing up the car (average = 0.3), a lapse in driver performance.

Impact of Hands-free Cellular Phone Use on Driving Performance

Hypothesis #1: The first hypothesis tested whether driving performance measures were impacted by the cellular phone-related distraction task, and to what extent. Separate paired t tests were run on the means and standard deviations of each driving performance measure (mean velocity, lane offset, steering angle, and brake pressure) across each drive. Figures 2 through 5 show the means and standard errors for the driving measures (means and standard deviations/variability) by distraction condition. Mean velocity (Figure 2a) was higher when participants were engaged in the distraction task than when only driving, $t(19) = -2.41$, $p < 0.05$, $d = 1.28$; velocity was also significantly more variable during the distraction condition than in the driving-only condition, $t(19) = -2.52$, $p < 0.05$, $d = 1.16$ (Figure 2b). Participants drove significantly closer to the lane divider line in the distraction condition than in the driving-only condition, $t(19) = -3.16$, $p < 0.01$, $d = 1.04$ (Figure 3a), although variability in lane position was only marginally significantly different between the two conditions, $t(19) = 1.99$, $p = 0.06$, $d = 0.83$, with the distraction condition actually tending toward less variability than driving only (Figure 3b). Steering was more variable in the distraction condition than in the driving-only condition, $t(19) = -2.38$, $p < 0.05$, $d = 1.64$ (Figure 4b). No other comparisons of the driving performance measures, including braking measures (see Figure 5), resulted in significant differences.

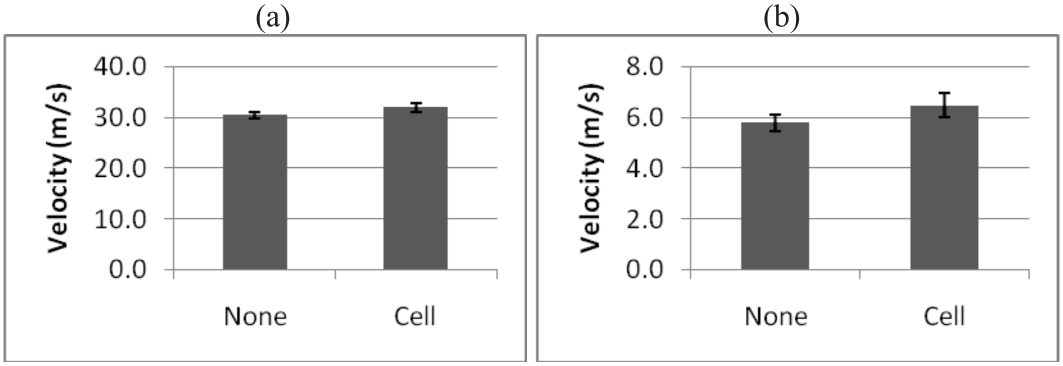

Figure 2. Means (a) and standard deviations (b) by distraction condition for velocity (m/s). Error bars represent the standard error of the mean.

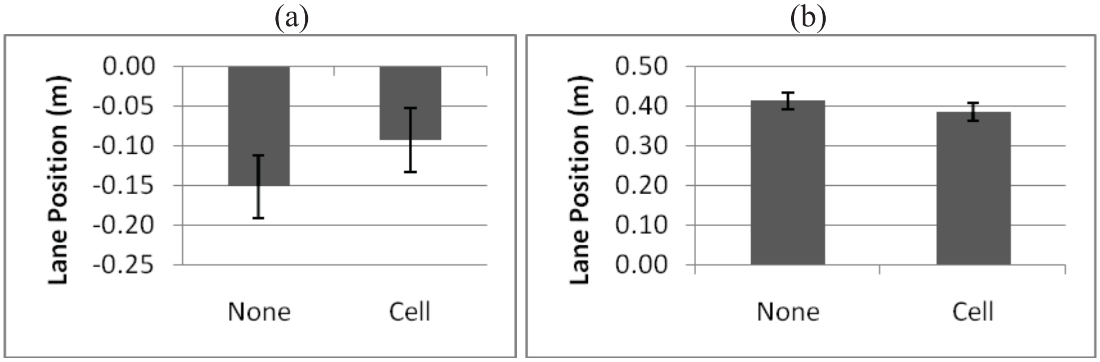

Figure 3. Means (a) and standard deviations (b) by distraction condition for lane position (in meters). Error bars represent the standard error of the mean.

In addition to the overall means for the driving performance measures for each drive, an analysis of variance (ANOVA) was also conducted for each driving measure on the means and standard deviations for the individual driving scenarios (i.e., the straight highway segments), with drive as a between-subject variable and scenario and distraction condition as the within-subject variables. The only significant effects on the means were scenario on steering angle, $F(2, 34) = 24.87$, $p < .0001$, $\eta^2 = 0.59$, and velocity, $F(2, 34) = 93.97$, $p < .0001$, $\eta^2 = 0.84$; this is primarily due to the vehicle having to accelerate and enter the roadway in the first segment but not in the second or third scenarios (see Figures 6 and 7). There were no significant interactions.

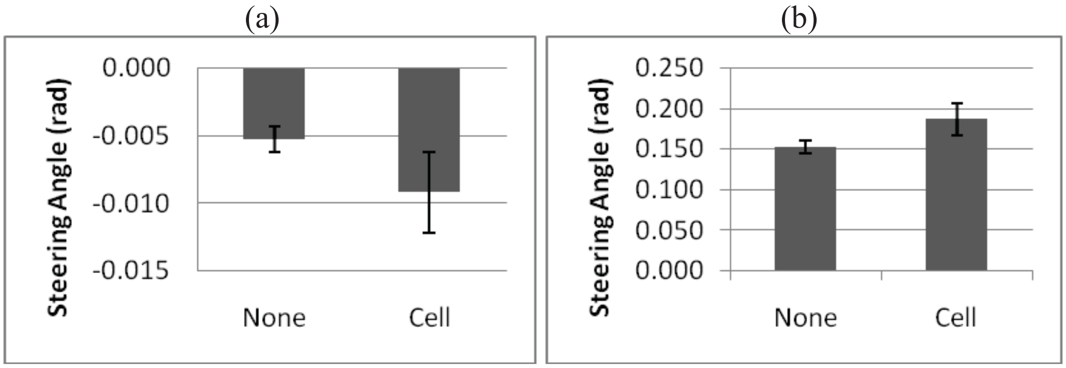

Figure 4. Means (a) and standard deviations (b) by distraction condition for steering angle (in radians). Error bars represent the standard error of the mean.

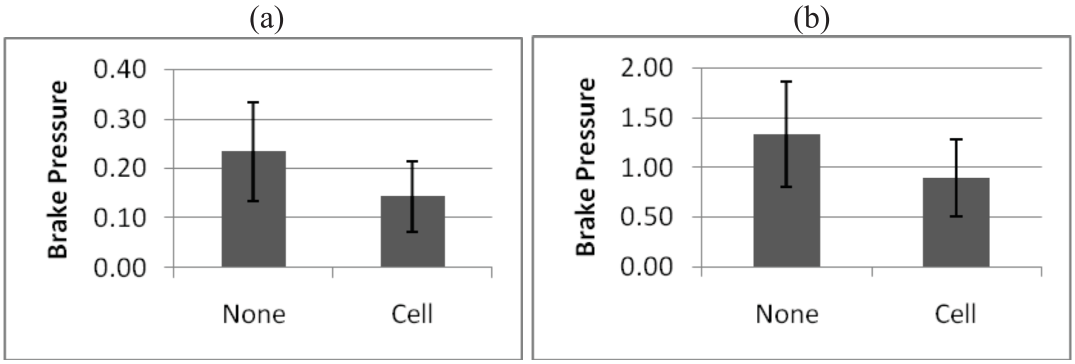

Figure 5. Means (a) and standard deviations (b) by distraction condition for brake pressure. Error bars represent the standard error of the mean.

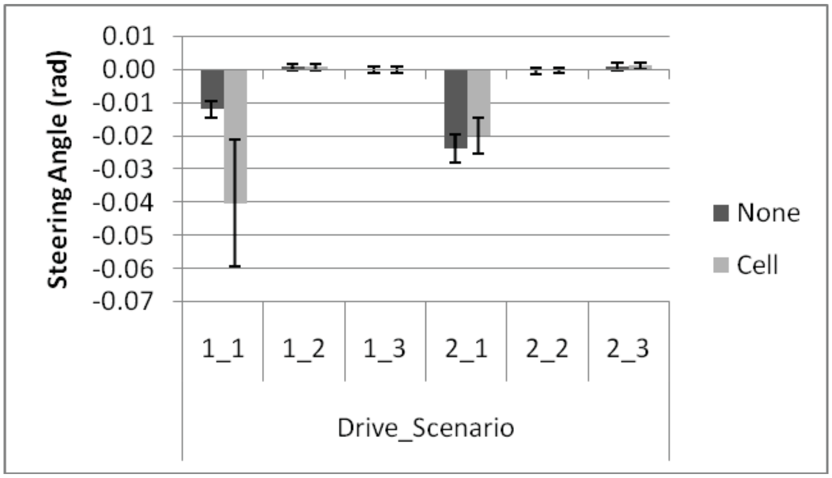

Figure 6. Scenario means by distraction condition for steering angle. Error bars represent the standard error of the mean.

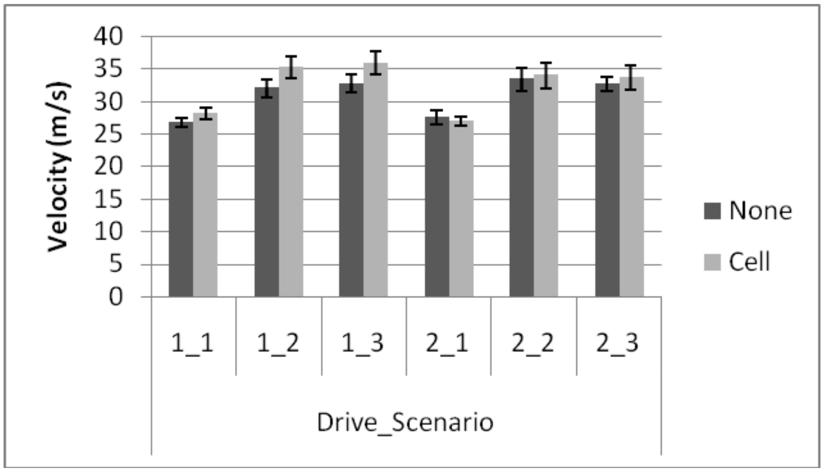

Figure 7. Scenario means by distraction condition for velocity. Error bars represent the standard error of the mean.

In order to separate out the impact of the first scenario on the driving measures, additional ANOVAs were completed on only the second and third scenarios for each driving measure (means and standard deviations). The only main effect obtained across the means for the driving measures was for distraction on mean velocity, $F(1, 17) = 6.99$, $p < .05$, $\eta^2 = 0.28$ (see Figure 7); participants drove faster in the distraction condition than in the driving-only condition. There was an additional distraction × scenario interaction on mean lane position, $F(1, 17) = 6.67$, $p < .05$, $\eta^2 = 0.28$, although neither main effect was significant (Figure 8). Participants in the distraction condition drove closer to the center of the lane during the second scenario in the first drive, but not during the second drive.

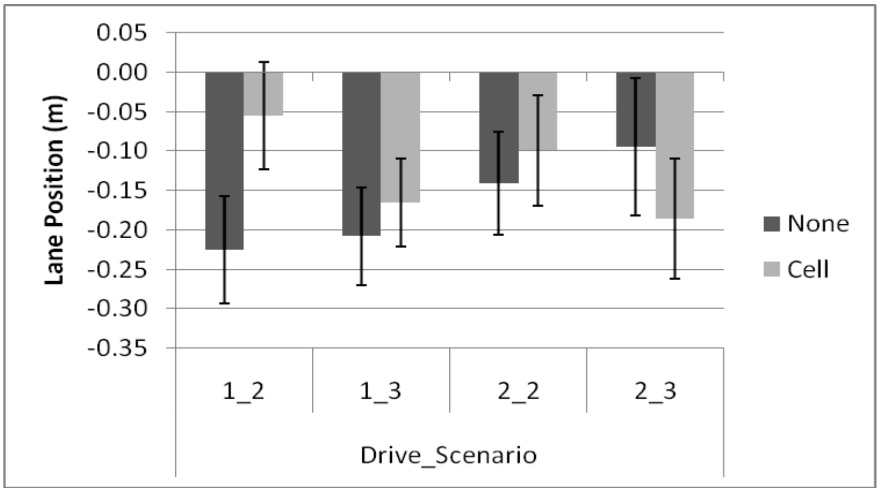

Figure 8. Means by distraction condition for lane position for the second and third scenarios of each drive. Error bars represent the standard error of the mean.

As was the case for the overall driving performance measures, ANOVAs were also generated comparing the standard deviations for the driving performance measures across the driving scenarios. Figure 9 shows the standard deviations for steering angle; steering was more variable when participants were maintaining a conversation while driving than when participants were only driving, $F(1, 17) = 5.82$, $p < .05$, $\eta^2 = 0.21$. There were also two significant interactions: distraction × drive, $F(1, 17) = 4.60$, $p < .05$, $\eta^2 = 0.17$, and distraction × scenario, $F(2, 34) = 4.54$, $p < .05$, $\eta^2 = 0.18$. Once the Greenhouse-Geisser correction was applied, a three-way interaction (distraction ×

scenario × drive) was marginally significant, $F(2, 34) = 3.41$, $p < .08$, $\eta^2 = 0.14$; this trend seems to reflect a greater effect of distraction on steering variability in the first drive, compared to the second drive in which participants have more experience with the specific steering characteristics of the simulator.

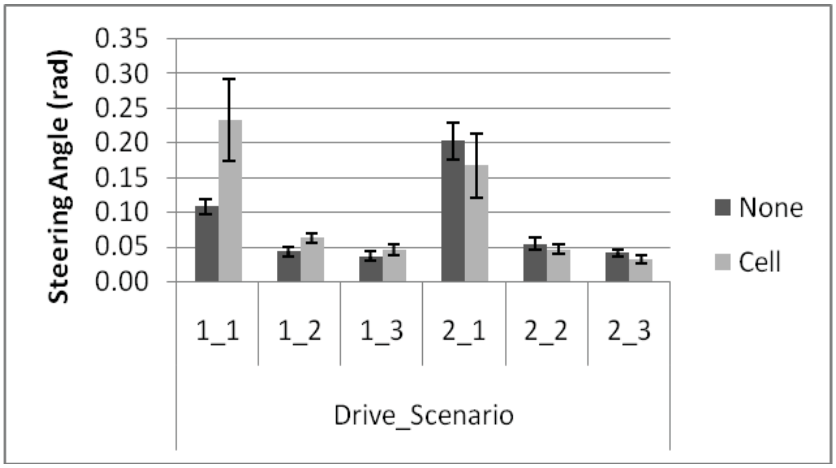

Figure 9. Scenario standard deviations by distraction condition for steering angle. Error bars represent the standard error of the mean.

To further investigate the interactions involving drive for variability in steering angle, the two drives were then analyzed separately, this time with distraction as a between-subject variable. For the first drive, there was a significant effect of distraction, $F(1, 17) = 5.59$, $p < .05$, $\eta^2 = 0.25$, scenario, $F(2, 34) = 19.57$, $p < .001$, $\eta^2 = 0.48$, and a marginally significant distraction × scenario interaction, $F(2, 34) = 3.94$, $p < .07$, $\eta^2 = 0.10$, reflecting the trend for greater variability in the first scenario (including entering the roadway), particularly in the distraction condition. This marginal interaction was significant prior to the Greenhouse-Geisser correction. For the second drive, there were no differences due to distraction, but there was an effect of scenario, $F(2, 34) = 35.08$, p

$< .0001$, $\eta^2 = 0.67$; unlike the results in the first drive, there was no indication of a distraction × scenario interaction for the second drive.

With regard to the other driving measures, there was a significant effect of scenario on the variability of velocity, $F(2, 34) = 66.55$, $p < .0001$, $\eta^2 = 0.79$, primarily due to acceleration during the first scenario (see Figure 10). Neither of the other driving measures (i.e., braking and lane offset) showed significant differences in variability.

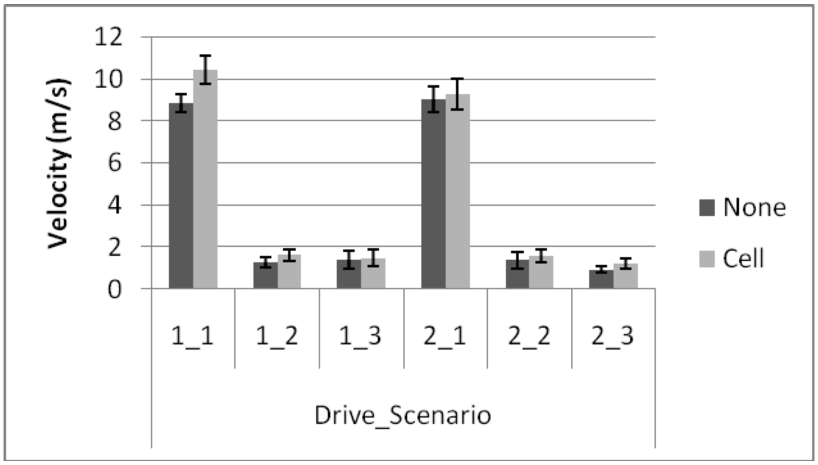

Figure 10. Scenario standard deviations by distraction condition for velocity. Error bars represent the standard error of the mean.

As was the case with the means, the variability of the driving measures were analyzed for the second and third scenarios of each drive to eliminate potential masking of differences by the larger variability present in the first scenario. There were some significant differences found regarding variability in the driving measures, specifically in lateral vehicle control (Figures 11 and 12). Variability for steering angle varied between the second and third scenarios, $F(1, 17) = 30.44$, $p < .0001$, $\eta^2 = 0.63$ (Figure 11); steering was more variable for the second scenario than for the third scenario of each drive. The effect of distraction condition on variability in lane position was also marginally significant, $F(1, 17) = 4.16$, $p = .06$, $\eta^2 = 0.20$ (Figure 12), indicating a trend for less variability in lane position in the distraction condition than in driving-only condition. This trend is similar to that obtained for the overall measures (Figure 3b).

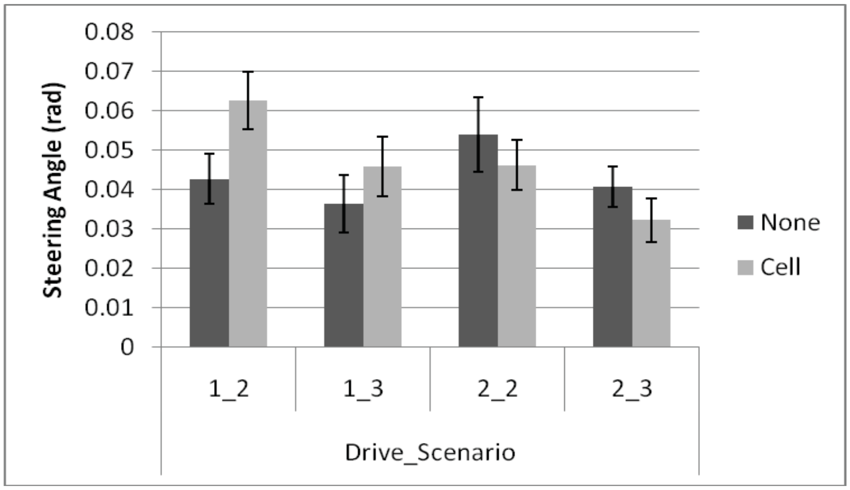

Figure 11. Standard deviations by distraction condition for steering angle for second and third scenarios of each drive. Error bars represent the standard error of the mean.

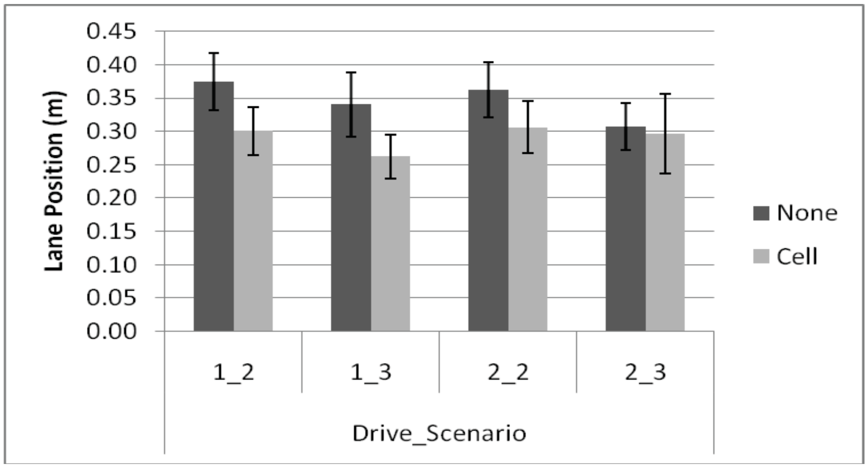

Figure 12. Standard deviations by distraction condition for lane position for second and third scenarios of each drive. Error bars represent the standard error of the mean.

Hypothesis #2: It was anticipated that braking responses would be slower and more braking pressure will be applied as a compensation strategy, similar to the test track results of Hancock et al., 1999. However, as previously indicated (Hypothesis #1), there were no significant differences in braking behavior across the current drives; thus, the braking aspect of this hypothesis is not supported (in contrast to Hancock et al., 1999). This result is likely due to the nature of the driving environment, in which drivers were on a four-lane divided highway without any hazards that required an abrupt evasive maneuver or emergency braking.

Hypotheses #3 and #4: Based on Strayer et al.'s (2003) results, Hypothesis #3 stated that there would be no difference in eye tracking patterns based on the distraction condition. Hypothesis #4 tested whether participants looked at hazards more frequently than at billboards, perhaps due to their task relevance and central proximity in the driving environment. Signs were expected to be intermediate to hazards and billboards in the number and duration of gazes. Figure 13 shows the mean number of gazes, based on distraction condition and driving relevance for each drive. Not surprisingly, there were instances when a participant gazed at an object multiple times as well as instances when a participant did not gaze at all on a particular object. Figure 14 shows what proportion of each relevance category received gazes by distraction condition.

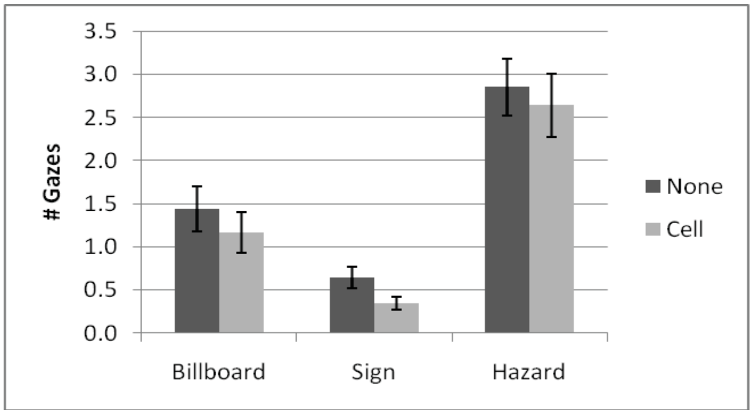

Figure 13. Mean number of gazes for critical objects by distraction condition and relevance. Error bars represent standard error of the mean.

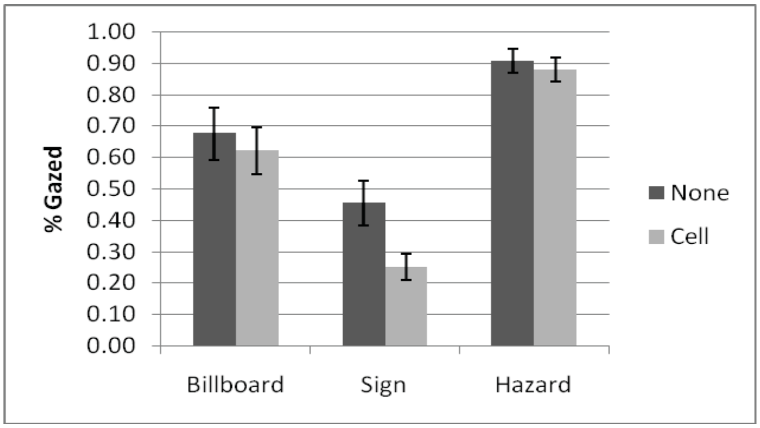

Figure 14. Proportion of critical objects receiving gazes for each relevance category by distraction condition. Error bars represent the standard error of the mean.

An ANOVA was conducted on mean proportion of critical objects receiving gazes with drive as a between-subject variable, and distraction and relevance as within-subject variables. In contrast with Strayer et al.'s (2003) findings, and with my expectations (Hypothesis #3), eye movement patterns differed between the driving-only and distraction conditions. There were main effects of distraction, $F(1, 16) = 4.52$, $p < .05$, $\eta^2 = 0.22$, and relevance, $F(2, 32) = 72.20$, $p < .0001$, $\eta^2 = 0.82$. There were no significant interactions, including distraction × relevance, $F(2, 32) = 2.41$, $p = .11$. Thus, there were fewer gazes toward the critical objects in the distraction condition, and hazards received more gazes than billboards, which received more gazes than signs. Hypothesis #4 was thus partially supported, although the expectation for signs being intermediate to hazards and billboards was clearly not met for the mean number of gazes. One potential explanation for why signs received fewer gazes than either billboards or hazards may be their smaller size in the environment. Signs may not attract attention as easily in the environment, they may be overlooked, or gazes that did occur on the signs may be harder to distinguish from nearby objects because of a combination in error in eye tracking recording and a relatively small target object.

Although my original goal was to evaluate both mean number of gazes and mean gaze duration across the distraction and relevance manipulations, the resulting data contain too many missing values for duration to analyze successfully. No critical object received a gaze in all cases, and thus every critical object has some missing data for duration (i.e., there was no gaze to be counted for that object of any duration). Figure 15 shows the resulting mean durations for each distraction and relevance manipulation, labeled with the available number of observations. The maximum number of observations possible per cell is eighteen. The available data suggest that gaze durations were shorter for the distraction condition than for the driving-only condition.

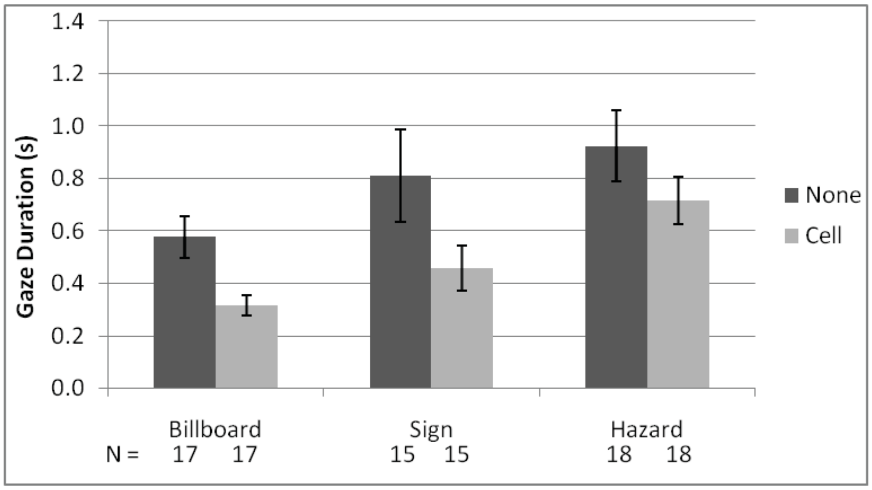

Figure 15. Mean gaze duration (in seconds) for critical objects by distraction condition and relevance for all participants. Error bars represent the standard error of the mean. *N* values indicate actual number of participants who gazed on at least one critical object for each relevance category.

An ANOVA was conducted on the gaze duration means that were available, resulting in 11 (of 18) participants being included, with drive as a between-subject variable, and distraction and relevance as within-subject variables. The means for the included data are shown in Figure 16. The only significant main effect was relevance, $F(2, 18) = 9.65$, $p < .01$, $\eta^2 = 0.47$. In contrast to the results for mean number of gazes, the pattern of the gaze duration data does follow the expected progression from billboards, to signs, to hazards in increasing duration. Thus, there is some evidence that driver eye movement patterns, and thus driver attention, are sensitive to objects' relevance to the driving task. It is possible that a distraction effect might be precluded by a lack of power due to the limited number of participants, because there is a clear trend toward shorter gazes in the cell phone distraction condition.

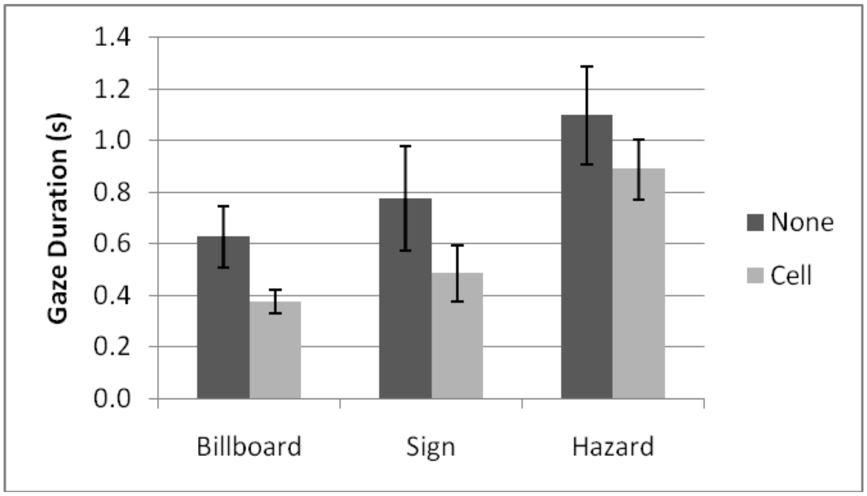

Figure 16. Mean gaze duration (in seconds) for critical objects by distraction condition and relevance for participants included in the ANOVA. Error bars represent the standard error of the mean.

Occurrence of Inattentional Blindness

Hypotheses #5 and #6: It was hypothesized that eye movement results would reflect that participants looked at the driving-relevant and -irrelevant environmental objects equivalently between the driving conditions (i.e., hazards and billboards; but see analysis above for Hypothesis #3), but the memory task results would indicate a greater lack of attention and recognition of critical objects in the distraction condition compared to the driving-only condition. It was also anticipated that recognition accuracy would be lower in the distraction condition than in the driving-only condition. Additionally, an effect of driving relevance was also expected, because it was anticipated that drivers may pay more attention to more relevant information and thus be more likely to recognize it. An ANOVA was conducted on recognition accuracy with type of recognition test (Old/New vs. 2AFC) as a between-subject variable and relevance and distraction as within-subject variables. For the Old/New test, sensitivity (A-prime) values were calculated and compared to accuracy on the 2AFC test. There was no effect of type of recognition test (*F* < 1), so the data from the two test types were combined.

Figure 17 shows the overall recognition results, by distraction and relevance. Recognition was found to differ significantly across distraction conditions, *F*(1, 19) = 6.53, $p < .05$, $\eta^2 = 0.26$; however, there was no significant impact of driving relevance, *F*(2, 38) = 0.77, and no significant interaction, *F*(2, 38) = 0.26. Due to overall low recognition memory results, an additional set of *t* tests was conducted, comparing overall, distraction condition, and driving-only condition accuracy to a chance value of 0.5. Overall recognition (mean = 0.54) differed significantly from chance performance, *t*(19) = 2.17, $p < .05$, as did recognition in the driving-only condition (mean = 0.59), *t*(19) = 3.53, $p < .01$. However, recognition in the distraction condition (mean = 0.49) did not differ from chance, *t*(19) = -0.45.

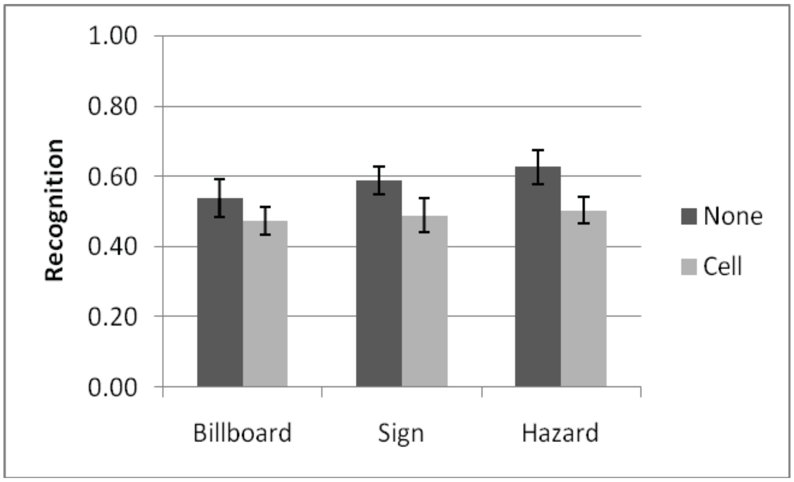

Figure 17. Mean overall recognition for critical objects by distraction condition and relevance. Error bars represent standard error of the mean.

Figure 18 shows the mean recognition limited to only those objects that received gazes. As was the case with the gaze duration data, there were too many missing values once the critical items that did not receive gazes were dropped from the analysis. Although there is some evidence that the distracting task may lead to inattentional blindness, the relationship is not clear across the distraction conditions. Both signs and hazards seem to show an effect of distraction, with participants recognizing fewer of those critical objects when they were presented in the distraction condition than in the driving only condition. However, memory for billboards seems to be similar for both the distraction and driving-only conditions; this is in contrast to Strayer et al.'s (2003) results, in which they obtained a distraction effect on recognition memory only using billboards as critical objects.

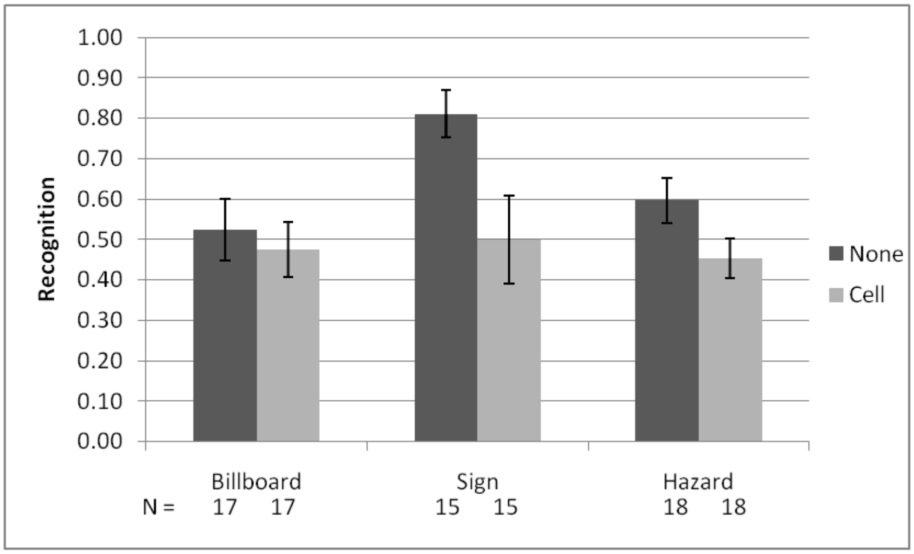

Figure 18. Mean recognition for only critical objects receiving gazes by distraction condition and relevance. Error bars represent standard error of the mean. *N* values indicate actual number of participants who gazed on at least one critical object for each relevance category.

An ANOVA was conducted on the mean recognition results that were available, conditional on the critical object having received a gaze during the driving task. As was the case with the gaze duration data, some participants were dropped from the analyses due to missing values (i.e., no gazes on any of the critical objects in a relevance category for a drive). The resulting ANOVA included 11 (of 18) participants, with drive as a between-subject variable, and distraction and relevance as within-subject variables. The only significant main effect was for distraction, $F(1, 10) = 11.18$, $p < .01$, $\eta^2 = 0.53$, with participants recognizing more critical objects presented during drives during which there was no distraction compared to drives with an ongoing conversation. The greatest difference between the overall and gaze-only recognition results appears to be recognition of the sign objects. Combined with the gaze results, which indicated that participants were least likely to gaze at signs than other objects, these results indicate that participants were likely to remember the signs if they received gazes. The patterns for billboards and hazards are more consistent between the overall and gaze-only analyses.

Hypothesis #7: It was hypothesized that the general trends across recorded eye movements and driving performance might indicate that participants responded to potential hazards (by looking at them, slowing down, steering away from the hazard, etc.), even when memory test results indicated a lack of attention. Separate ANOVAs were run for each of the four driving measures (steering angle, brake pressure, velocity, and lane position) to determine whether there were any differences in performance present when participants recognized the hazard and when they did not, with accuracy (levels = 0, 0.5, 1) as a class variable and distraction and scenario as within-subject variables. There were no differences due to recognition accuracy for any of the driving performance measures. Therefore it appears that the participants responded to hazards similarly regardless of whether or not they recognized the hazard when tested.

Given that participants seem to drive similarly around hazards based on the lack of differences in recognition memory, comparisons were then made across the distraction and relevance manipulations. Figures 19 through 21 show the means and standard errors for the driving measures (means and standard deviations/variability) by relevance and distraction condition. Separate ANOVAs were run to compare the four driving performance measures (steering angle, brake pressure, velocity, and lane position) and number of gazes based on distraction condition and relevance. Billboards were dropped from the analyses, so that comparisons could be made between the two driving-relevant categories: signs and hazards. The resulting ANOVAs can then be considered together so that general trends across the distraction conditions and relevance categories can be investigated in concert rather than individually.

There were apparent differences in how participants drove near potential hazards compared to signs, and these differences seemed to stay consistent between the distraction conditions. Mean steering angle varied by relevance, $F(1, 17) = 22.96$, $p < .001$, $\eta^2 = 0.45$, but there was no effect of distraction and no distraction × relevance interaction; the variability in steering angle (as measures by standard deviation) also differed by relevance, $F(1, 17) = 4.90$, $p < .05$, $\eta^2 = 0.22$ (see Figure 19). A mean steering angle value near zero means that the steering wheel was centered; positive values indicate the wheel is turned to the right and negative values to the left. Note that a difference of

0.05 radians converts to approximately 3 degrees. Thus, it appears that steering was roughly centered, with slightly greater variability when participants passed hazards than when they passed signs.

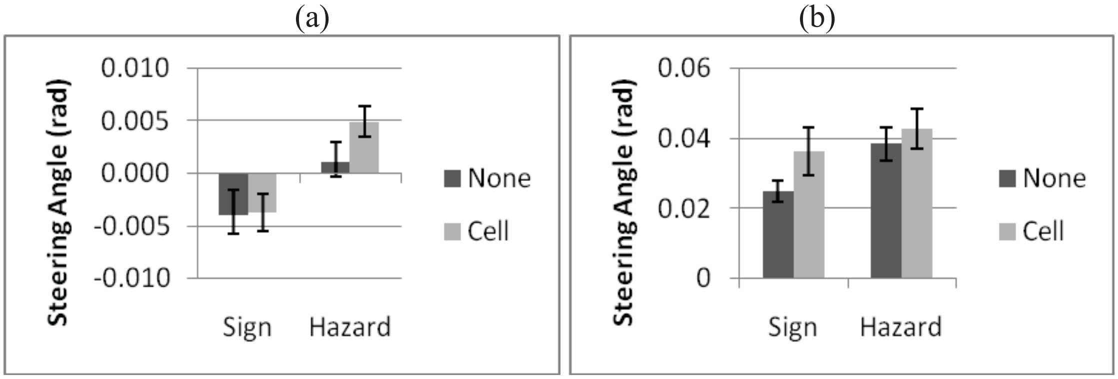

Figure 19. Means (a) and standard deviations (b) by distraction condition and relevance for steering angle (in radians). Error bars represent the standard error of the mean.

Similar to the steering angle results, mean lane position differed due to relevance, *F*(1, 17) = 24.81, *p* < .0001, η^2 = 0.56 (Figure 20a) and varied significantly more near hazards than near signs *F*(1, 17) = 21.11, *p* < .001, η^2 = 0.55 (Figure 20b), but again there was no effect of distraction or distraction × relevance interaction on either the means or standard deviations. Negative values for lane position indicate a position left of the center of the lane; the driving lanes were approximately 3.6 meters wide.

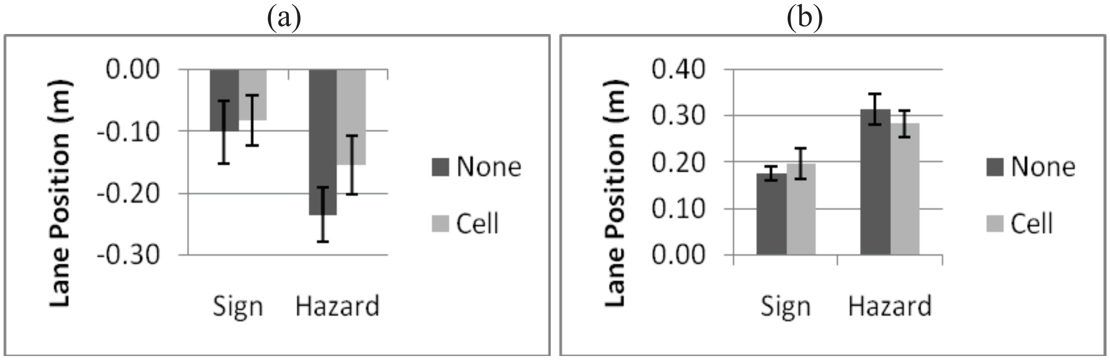

Figure 20. Means (a) and standard deviations (b) by distraction condition and relevance for lane position (in meters). Error bars represent the standard error of the mean.

Variability in velocity was not only sensitive to relevance, $F(1, 17) = 4.86$, $p < .05$, $\eta^2 = 0.22$, but also to distraction, $F(1, 17) = 4.56$, $p < .05$, $\eta^2 = 0.20$; however, there was still no distraction × relevance interaction (Figure 21). The pattern of the driving measures indicates that participants reacted to the potential hazards in a similar manner to that expected in actual on-road driving: participants slowed and moved away from potential hazards (i.e., moved toward the center of a lane with a potential hazard to the right). Additionally, participants seemed to respond to hazards similarly when distracted and when only driving, in contrast to expectations that distraction would impact driver recognition and response to potential hazards.

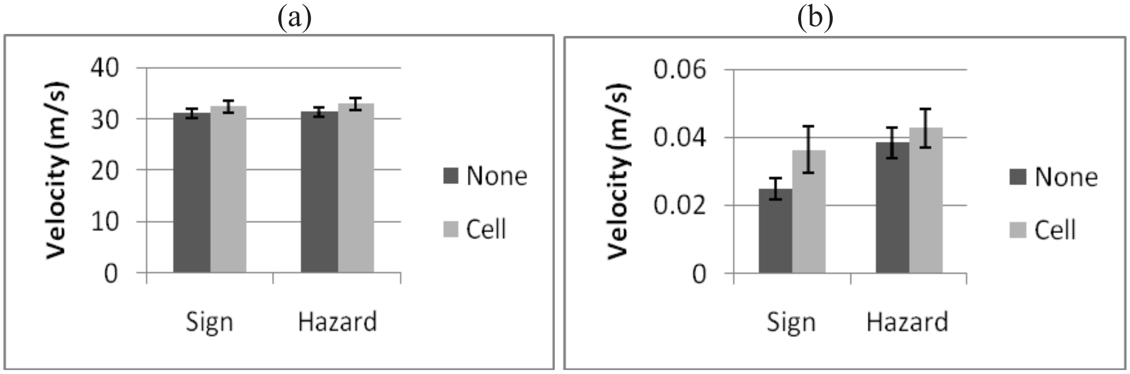

Figure 21. Means (a) and standard deviations (b) by distraction condition and relevance for velocity (m/s). Error bars represent the standard error of the mean.

Figure 22 shows the mean proportion of critical objects receiving gazes by relevance and distraction condition. In contrast to the driving measures, proportion of objects receiving gazes varied both due to relevance, $F(1, 16) = 133.55$, $p < .0001$, $\eta^2 = 0.89$, and distraction, $F(1, 16) = 8.45$, $p < .05$, $\eta^2 = 0.34$, and there was a significant distraction × relevance interaction, $F(1, 16) = 12.24$, $p < .01$, $\eta^2 = 0.41$. Drivers were less likely to gaze at signs when distracted, but there was no difference in the occurrence of gazes on hazards between the distraction conditions. The presence of a significant distraction × relevance interaction in the gaze measures but not in the driving measures suggests that eye movement patterns may be more sensitive to distraction than are driving measures (see Discussion for more evidence).

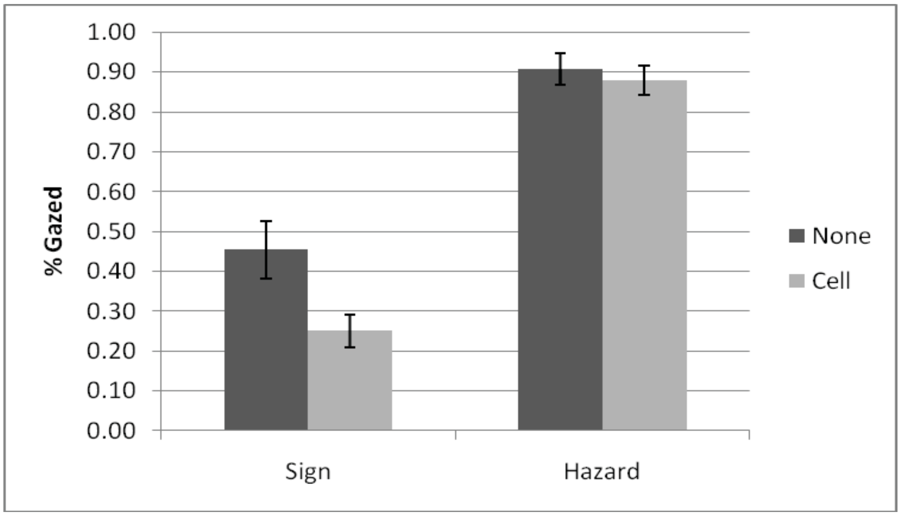

Figure 22. Proportion of critical objects receiving gazes for each relevance category by distraction condition (signs and hazards only). Error bars represent the standard error of the mean.

Summary

Similar to previous research findings (e.g., Strayer et al., 2003), driver distraction via a simulated cellular phone conversation impacted driver performance and visual attention measures. Both driving measures and eye movement patterns, as reflected in number of gazes, were sensitive to the driving relevance of roadside objects. However, there was no interaction of distraction and relevance on any of the driving measures, indicating that drivers may not have the capacity to allocate additional attention to potential hazards in an effort to compensate for the impact of driver distraction. Regarding the recognition memory test, the results were not clear. There were no relevance effects on recognition, breaking away from the patterns in the driving performance and eye movement results. However, there was evidence of inattentional blindness, given the significant impact of distraction condition on recognition memory for objects that received gazes. Because recognition was near chance levels, it may not be closely related to the more direct measures of driver performance and attention.

CHAPTER IV

DISCUSSION

As has been found in numerous previous research endeavors, driving performance was expected to become more variable with the addition of the cellular phone task as attention is drawn away from monitoring the driving task. It was expected that both longitudinal (i.e., velocity) and lateral (i.e., lane position, steering) control would show decrements compared to driving only (Hypothesis #1). However, lane position variability actually trended toward less variability rather than greater. Although unexpected, improved lateral control has been found in other simulated driving studies investigating distraction (Becic, Dell, Bock, Garnsey, Kubose & Kramer, 2010; Kubose, Bock, Dell, Garnsey, Kramer, & Mayhugh, 2006). Thus, these expectations were generally confirmed, indicating decreased vehicle control under the cellular phone-related distraction condition, at least during the first drive of the experiment. However, any differences between the distraction conditions were mostly eliminated during the second drive.

The lack of differences between the distraction and driving-only condition during the second drive may be due to participants continuing to adjust to the driving simulator's dynamics in general, due to the limited fidelity of the simulation compared to actual driving. Alternatively, it may also be an order or training effect in which participants who had additional driving time in the simulator without distraction learned the vehicle controls more effectively than those who experienced the distraction condition earlier (i.e., the first drive). Because the driving simulation environment differs from the actual driving experience in a number of ways (e.g., quality of visual information, lack of proprioceptive cues, vehicle dynamics, etc.), participants may need additional time to completely acclimate to the driving environment even after the initial familiarization drive has been completed. In this case, the elimination of differences between the distraction conditions may be because the participants in the driving-only condition may be more variable than were their counterparts who completed the driving-only condition first. Conversely, participants who first drove the driving-only condition may have acclimated to the simulation more effectively during the first drive, and thus were less directly impacted by the conversation during the distraction condition. The transfer of acquired skills has been found to be sensitive to training context in past research (e.g., Brou, Garrison, Doane, & Bradshaw, 2007; Doane, Sohn, & Schreiber, 1999). A further investigation of participant acclimation to and acceptance of driving simulation environments may allow researchers to generalize to real-world novice driver skill acquisition in controlled situations, providing further insight into the potential impact of driver distraction and multitasking earlier in driver training, when the skills involved are novel and accident risks are highest (e.g., Allen et al., 2007; NHTSA, 2009).

Although the driving performance measures are somewhat equivocal, the current project also includes other measures, including eye movement measures and recognition. At the most basic level, eye movement patterns were not expected to differ with the addition of the cellular phone task compared to driving only (Hypothesis #3); this hypothesis was not supported because critical objects received fewer gazes in the distraction condition than in the driving-only condition.

Despite not replicating Strayer et al.'s (2003) results (on which Hypothesis #3 was based), the current project's results replicate findings by other researchers indicating that drivers' gaze patterns are sensitive to distraction (e.g., Recarte & Nunes, 2003). Thus, it appears that there is still work left to be done in determining what aspects of distraction are most disruptive to visual attention mechanisms.

The impact of driver distraction on visual attention is central to the research of interest, in an effort to clarify and extend current understanding of how visual attention is impacted by distraction. In addition to the differences in eye movement measures due to distraction, eye movement measures were also found to vary based on driving relevance. Along with evaluating the impact of driving relevance on eye movement patterns, the current project was also designed to illuminate aspects of overt attention allocation in a complex task by considering eye movements, driving performance, and memory measures in combination. Evidence that eye movement measures differ between objects that are relevant versus irrelevant to the driving task supports previous results (e.g., Henderson, Malcolm & Schandl, 2009), indicating that attention is primarily allocated in a top-down manner (Hypothesis #3) and suggesting that the driving task maintained priority in the presence of another attention-demanding task. Further, there were also differences in how attention was allocated to hazardous events compared to 'relevant' road signs. Hazards received more gazes than signs, and participants shifted their lane position when near hazards more toward the center line than when they were near signs, reflecting what drivers would be expected to do on actual roadways.

The presence of a mismatch between the eye movement and memory task results regarding driving relevance may provide further evidence of inattentional blindness and attentional limitations (Hypothesis #5) because memory is worse for objects that received gazes under distraction conditions. Although driving relevance did not interact with recognition accuracy (Hypothesis #6), the generally low accuracy results suggest that memory may not be an effective measure of attention allocation for the primary driving task. The additional availability of attentional resources during the relatively non-demanding baseline driving task, compared to the secondary task condition, may allow for more processing of environmental features beyond what is strictly necessary to support effective driving performance (perceptual load, Cartwright-Finch & Lavie, 2007; Macdonald & Lavie, 2008; general interference, Crundall, Underwood, & Chapman, 2002). In contrast, the addition of the secondary task in the cellular phone conversation condition redirects attentional resources from processing the environment to task performance; thus, additional processing of the environment does not occur at a level to support later recognition performance. However, recognition performance does not directly reflect driving performance because a driver does not have to remember, or even definitively identify, an event or hazard to respond to it effectively.

Although recognition may not directly reflect driver performance, the combination of eye movement patterns with driving performance measures provides insight into drivers' responses to potential hazards and their conscious awareness of such responses (Hypothesis #6; see also Hayhoe, 2000). The results indicate that both relevance and distraction impacted driver performance, but there was no interaction between the two manipulations. However, the eye movement patterns did show an interaction between distraction and relevance in addition to main effects for distraction and relevance. These results support previous research findings in which distraction effects have been more robust in eye movement measures (Recarte & Nunes, 2003) than in driving performance measures, particularly lateral control (e.g., lane position, Kubose et al., 2006). It is also possible that the eye movements are more sensitive to specific differences in the type of information being processed than are the driving performance measures, which are primarily oriented toward response to changing conditions rather than the specific nature of the changes.

In addition to potential differences in measurement sensitivity, the lack of an interaction between distraction and relevance in the driving performance measures may indicate that drivers were able to respond to the stable potential hazards similarly when distracted than when not distracted. It is possible that driving is such an over-learned task in experienced drivers that drivers take action to avoid hazardous situations ‘automatically’; that is, drivers may be able to respond to the presence of a potential hazard without having to actively or consciously process it. For example, experienced drivers regularly process peripheral information to maintain lane position (Crundall & Underwood, 1998). A similar mechanism may be involved in monitoring and responding to objects that are perceived (whether centrally or peripherally) that may be about to enter the driving lane.

Another possible explanation is that the driving situations presented in the current study were not demanding enough to result in dramatic driver deficits. Some researchers (e.g., Kubose et al, 2006) have found *improved* lateral control under distraction conditions than in driving only in undemanding driving situations (e.g., straight roads with limited traffic). It is possible that the additional demands of the distraction task may lead drivers to attend more directly to vehicle maintenance. Alternatively, it may be that conscious control of lateral position is actually more difficult to maintain than automatic control for experienced drivers, as it requires small but precise motor control. The current project cannot distinguish between these two possibilities. Additionally, the most robust finding for driver distraction deficits is an increase in response time to critical events or stimuli (Caird et al., 2008); the current situations did not require any abrupt response but were directed toward more subtle and persistent impacts of distraction.

The relevance of environmental objects to the driving task has been shown here to impact driver attention; it is likely that the clutter of the driving environment also impacts driver attention (Horberry, Anderson, Regan, Triggs, & Brown, 2006), particularly for novice or older drivers who suffer from increased attentional demands. The driving environments in the current project were simplified due to simulation fidelity limitations and concerns about simulator sickness in a new driving simulator. Additionally, all of the objects of interest were in a limited area (the right side of the road), and thus the actual impact of distraction may be substantially greater than the results observed here indicate. Now that concerns about simulator sickness and simulator acceptance have been assuaged, further research in more complex driving environments can be conducted.

Overall, the conversation task clearly impacted vehicle control and visual attention, replicating previous results, but the impact is limited to a range that most drivers would consider acceptable. Indeed, some of the effects may not even be recognizable to drivers, such as the small increases in steering angle variability. Drivers have come to accept certain levels of distraction based on other common tasks (e.g., adjusting the climate control or radio volume, conversing with passengers, etc), even when these tasks may impact driver performance at a level comparable or beyond that of cellular phone use (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Stutts et al, 2005). However, the presence of both lateral and longitudinal control deficits for driver performance and evidence of attentional deficits even in these simplified, non-demanding conditions highlight the increased potential for risk and incidents, as real-world driving conditions can change dramatically in a very short period of time.

Applications

When driving performance measures are combined with eye movements, it becomes possible to observe participant reactions to driving-relevant events and objects in the environment that may not be apparent in the memory test results and similar evaluations. The current results also indicate that eye movement patterns may be more sensitive to distraction effects than are either driving performance measures or memory. Although it was already apparent that multitasking while driving leads to deficits in driving performance, prior to the current study it was less clear how deficits in performance may be mediated or moderated by event or object attributes. Because it was found that the relevance of an object to the driving task did impact driver performance, further investigation may lead to design approaches that can support driver attention and cognition in fields where driver multitasking is integral (e.g., emergency response, military, transit). A key to improving interface design in such situation is improving understanding of how attention is allocated across aspects of the environment, whether through spatial, relevance, or other channels; this is already an important goal of visual cognition research. A continued consideration of visual and performance measures together rather than in isolation may help address some of the questions that span structured laboratory tasks and real-world situations.

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APPENDIX A

EXPERIMENT CONSENT FORM

INFORMED CONSENT
for Participants in
Multitasking and Visual Attention in a Medium-fidelity Driving Simulator

Principal Investigators:
Teena Garrison, Graduate Research Assistant, CAVS
Dr. Ed Swan, Associate Professor, Computer Science and Engineering
Dr. Carrick Williams, Assistant Professor, Psychology

THE PURPOSE OF THIS STUDY: You are invited to participate in research investigating the eye movements and scan patterns involved in standard driving tasks. The data acquired in this study will be used to better understand what visual information is important in successfully completing driving maneuvers. This research will increase general scientific knowledge about information processing and decision making practices during driver multitasking.

PROCEDURE: We will ask that you complete driving tasks similar to those completed during everyday driving. You may also be asked to complete other common tasks while driving (e.g., having a conversation over a cellular phone). In addition, you will be asked to complete a questionnaire which asks some general questions about you. The total expected time of participation is about two hours.

RISK AND BENEFIT OF THIS RESEARCH: You should be aware that there is a possibility of simulator sickness due to motion cues provided by the motion base and the simulator display. Please inform the experimenter if any symptoms are experienced, at which time the simulation will be stopped. Questions will be asked that may seem embarrassing or strange, including questions about bodily functions. These questions are asked in order to minimize adverse effects due to the simulator system; any responses to these questions, as with all data collected during this study, will be kept confidential.

Additionally, when exposed to any form of video display, there is a possibility that sensitive individuals may experience an epileptic reaction. For this reason we regret that we cannot accept volunteers with a past history of epilepsy. We do not wish to aggravate any physical or psychological conditions; please discuss any concerns with the researcher.

Your participation in this study will provide information that will be used to advance our understanding of the attentional demands and potential risks of driver multitasking.

EXTENT OF CONFIDENTIALITY: Individual identities will be protected and all participant responses will be kept confidential. To protect the confidentiality of this information, each participant will be assigned a code number that will only be known to the researcher who collects the data. The purpose of the code number is to link all pieces of a participant's data together. All of the information provided to the research project members will be marked with the code number, except the informed consent. This code number will never be put on the informed consent or be linked to the informed consent in any manner. Video and audio data may be collected and transcribed to a file with only the participant code number as identification. Any personal details, names, etc. mentioned will be removed. No identifying information will be included in the resulting transcripts. The demographic information that you provide will be stored in a separate location from performance data to reduce the possibility that your performance data may be identified based on the demographic data that you provide. Personal details provided in the demographic questionnaire that may identify your participation will not be released.

All video information (eye tracking or otherwise) will be stored anonymously on a password-protected computer. In order to pursue external funding, some videos may be released to various funding agencies (e.g.,

MSU IRB
Approved: 6/29/09
Expires: 6/15/10

NSF, NTSB, NHTSA). When possible, identifying items or features, such as jewelry, will be removed prior to recording, or rendered illegible using video editing tools before releasing any videos to prospective funding agencies. Likewise, if individuals other than the researchers appear in the videos, their faces and other identifying features will be rendered unidentifiable using video editing tools before releasing any videos to prospective funding agencies. If, for any reason, identifying features cannot be removed, the video will not be released.

COMPENSATION: You will receive $20 in compensation for two hours of your time, with two circumstances being exceptions: In the case of lost data due to technical problems, you will be paid at a rate of $10/hour rounded to the nearest half-hour. For instance, if a technical issue precluded the conclusion of the experiment after an hour and fifteen minutes, you would receive $15 (for 1.5 hours at $10/hour). Additionally, if you choose to withdraw your consent at any time prior to completion of the experiment, you will be also paid at a rate of $10/hour rounded to the nearest half-hour.

FREEDOM TO WITHDRAW: You are free to decline to answer any question, stop any task, or withdraw from this study at any time for any reason without penalty. If you decide to participate or withdraw, no one except the researcher will be privy to that information.

APPROVAL OF THIS RESEARCH: The research project has been approved by the Institutional Review Board at Mississippi State University for projects involving human participants.

PARTICIPANT RESPONSIBILITIES: Participants should notify the researcher at any time about a desire to discontinue participation or of any medical conditions that may interfere with results or increase the risk of injury or illness.

PARTICIPANT'S PERMISSION: If you have any questions, please ask the researcher at this time. If you understand the above information and voluntarily consent to participate in the experiment entitled "Multitasking and Visual Attention in a Medium-fidelity Driving Simulator," please sign your name below. You will be given a copy of this consent form to keep for your records.

Signature: ______________________________ **Date:** ____________________

Printed Name: ____________________________

Researcher: ______________________________

For further information about this research, please contact: Teena Garrison, teenag@cavs.msstate.edu, at CAVS; Dr. Ed Swan, swan@cse.msstate.edu, at the Department of Computer Science and Engineering; or Dr. Carrick Williams, cwilliams@psychology.msstate.edu, at the Department of Psychology. If you have additional question regarding your rights as a human participant in this research, you may contact the Mississippi State Regulatory Compliance Office at (662) 325-2238.

APPENDIX B

PARTICIPANT QUESTIONNAIRES

Please indicate your interest in the following topics:

CURRENT EVENTS

National (US) News:

___ Very Interested ___ Somewhat Interested ___ Not Interested

World News:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Business:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Politics:

___ Very Interested ___ Somewhat Interested ___ Not Interested

SPORTS

Football:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Baseball:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Basketball:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Auto Racing:

___ Very Interested ___ Somewhat Interested ___ Not Interested

ENTERTAINMENT

Music:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Television:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Books:

___ Very Interested ___ Somewhat Interested ___ Not Interested

Video Games:

___ Very Interested ___ Somewhat Interested ___ Not Interested

DEMOGRAPHIC QUESTIONNAIRE

Date of Birth_____________ Gender _____

What year did you become a licensed driver? ________

Years of Education (please circle)	9	10	11	12	(High School)
	13	14	15	16	(College)
	17	18	19	20	(Postgraduate)

Do you own a cellular phone (yes/no)? _____

Do you use your cellular phone while driving (yes/no)? ______

If yes, how often:

Once a day___ Two or three times a week____ Less than once a week ___

If yes, for how long at a time:

More than 15 minutes ___ 5-7 minutes ____ Less than 2 minutes ___

Do you play video games (yes/no)? _____

If yes, how often:

Once a day___ Two or three times a week____ Less than once a week ___

If yes, for how long at a time:

More than 2 hours ___ 1-2 hours ____ Less than 1 hour ___

If yes, what genre(s):

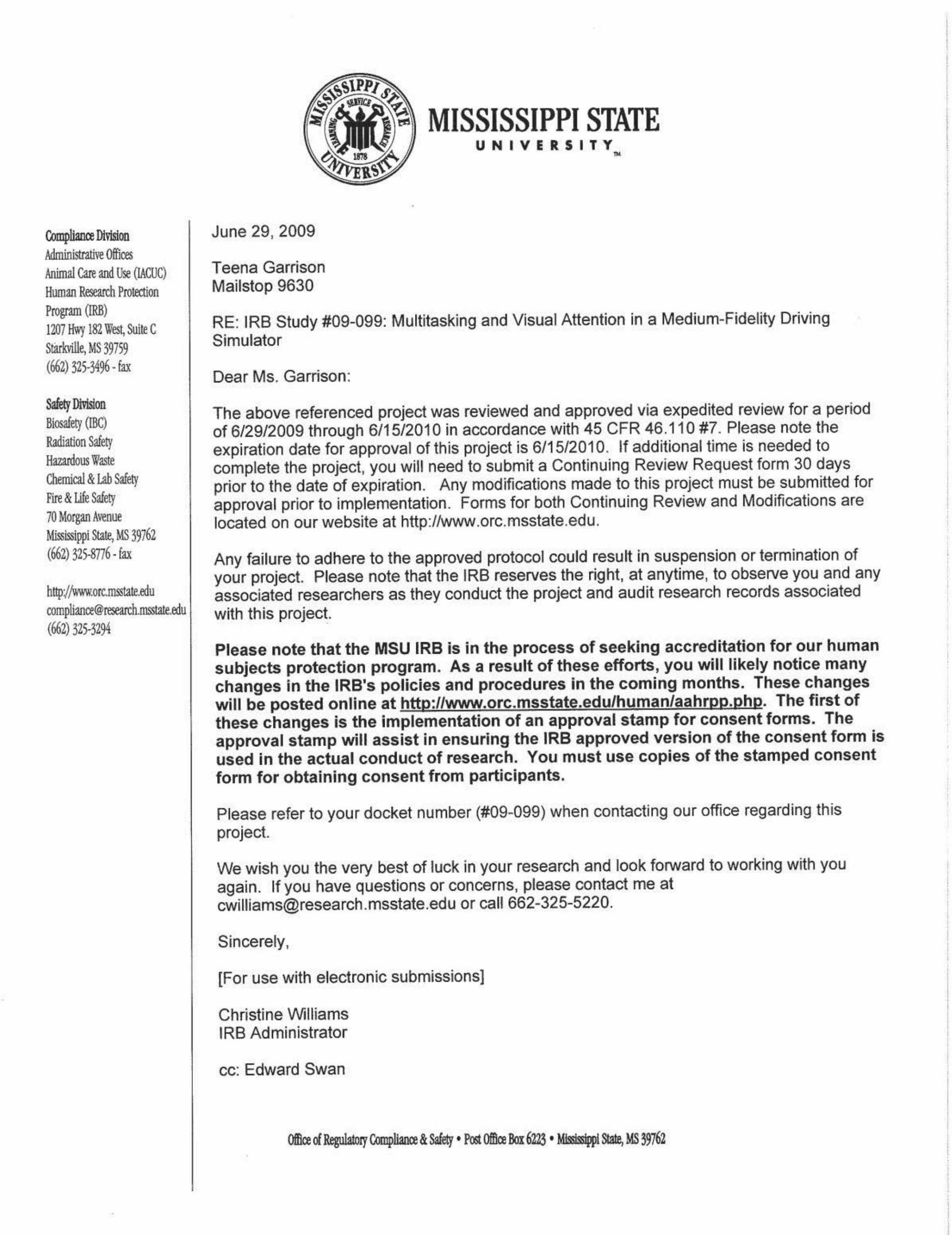
Racing ___ Sports ____ First-Person Shooter ___

Role-Playing ____ Strategy ___ Platform ___

Other ___ Please explain: __________________

APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL FORM



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Administrative Offices
Animal Care and Use (IACUC)
Human Research Protection
Program (IRB)
1207 Hwy 182 West, Suite C
Starkville, MS 39759
(662) 325-3496 - fax

Safety Division
Biosafety (IBC)
Radiation Safety
Hazardous Waste
Chemical & Lab Safety
Fire & Life Safety
70 Morgan Avenue
Mississippi State, MS 39762
(662) 325-8776 - fax

http://www.orc.msstate.edu
compliance@research.msstate.edu
(662) 325-3294

June 29, 2009

Teena Garrison
Mailstop 9630

RE: IRB Study #09-099: Multitasking and Visual Attention in a Medium-Fidelity Driving Simulator

Dear Ms. Garrison:

The above referenced project was reviewed and approved via expedited review for a period of 6/29/2009 through 6/15/2010 in accordance with 45 CFR 46.110 #7. Please note the expiration date for approval of this project is 6/15/2010. If additional time is needed to complete the project, you will need to submit a Continuing Review Request form 30 days prior to the date of expiration. Any modifications made to this project must be submitted for approval prior to implementation. Forms for both Continuing Review and Modifications are located on our website at http://www.orc.msstate.edu.

Any failure to adhere to the approved protocol could result in suspension or termination of your project. Please note that the IRB reserves the right, at anytime, to observe you and any associated researchers as they conduct the project and audit research records associated with this project.

Please note that the MSU IRB is in the process of seeking accreditation for our human subjects protection program. As a result of these efforts, you will likely notice many changes in the IRB's policies and procedures in the coming months. These changes will be posted online at http://www.orc.msstate.edu/human/aahrpp.php. The first of these changes is the implementation of an approval stamp for consent forms. The approval stamp will assist in ensuring the IRB approved version of the consent form is used in the actual conduct of research. You must use copies of the stamped consent form for obtaining consent from participants.

Please refer to your docket number (#09-099) when contacting our office regarding this project.

We wish you the very best of luck in your research and look forward to working with you again. If you have questions or concerns, please contact me at cwilliams@research.msstate.edu or call 662-325-5220.

Sincerely,

[For use with electronic submissions]

Christine Williams
IRB Administrator

cc: Edward Swan

Office of Regulatory Compliance & Safety • Post Office Box 6223 • Mississippi State, MS 39762