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MINIMIZING DRIVER ERRORS: DETECTING UNEXPECTED TARGETS IN FAMILIAR ENVIRONMENTS

Final Report

by

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DISCLAIMER

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EXCUTIVE SUMMARY

Talking on a cell phone can impair driving performance (e.g., Stayer & Drews, 2007), but the specifics of when common attentional resources are needed are not fully understood. We examined the effects of varying the visual attention load of the driving task by manipulating familiarity with the driving environment and presence of attention demanding driving elements (pedestrians and crosswalks). To vary familiarity with the driving environment, participants completed six runs through the same driving environment in a driving simulator. To vary attention to driving elements, there were two crosswalks with pedestrians on the side of or in the road. Half of the participants left voicemail messages on a new topic on each run (e.g., Talk about the classes your taking this semester, Talk about your favorite TV show or recent book you read) using a hands-free headset, while the other half drove in silence. In order to determine the effects of the visual attention demanding events on driving for participants who left voicemails versus those that did not, we measured velocity and steering deviation across four critical sections (45-30, 30-15, and, 15-0 meters before the crosswalks, and 0-15 meters after the crosswalks) of the last four driving runs. Leaving a voicemail increased steering deviation and velocity. However, the size of these effects decreased for the later runs, and was largest close to the crosswalks. This suggests that as more attention is needed in the visual environment, because the environment is less familiar and/or there are critical visual targets to attend to (pedestrians), leaving a voicemail leads to more erratic driving behavior (faster and more steering deviation). These results demonstrate that leaving a voicemail requires attentional resources and can impair driving performance. These effects are larger in unfamiliar driving environments that require a lot of attention (near crosswalks or in heavy traffic or construction zones). Therefore, training, driving laws, and cell phone/car design could be modified to reduce talking on a cell phone under these conditions.

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1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

Driving is a common task that requires the use of limited cognitive resources. For example, while driving, it is important to monitor the location of other cars on the roadway, the location of pedestrians, and scan the environment for traffic signs. In addition, other tasks that require attentional resources are often completed while driving. However, the number of items that can be attended at a given time is fewer than five (Cowan, 2001) and could be as few as one item (Öztekin et al. 2010). Consequently, some information is selected for processing more completely than other information, leading to a lack of awareness for the non-attended, and possibly critical, information (Simons & Chabris, 1999). For example, while attending to an accident on the side of the road or while talking on the cell phone, a driver may fail to notice a pedestrian entering the roadway, the break lights illuminating on the car in front of them, or a merging-lanes traffic sign. A critical question to answer in order to determine under what circumstance important information is likely to not be attended and therefore, not detected, is, "What determines where a driver will be attending from one moment to the next?" In the current study we examined the role of talking on cell phones and familiarity with the driving environment on driving performance.

1.2 PROJECT OBJECITVES

Critical to the driver's performance is the ability to detect critical items quickly. For example, if a pedestrian steps into the street, the more readily the driver detects the pedestrian, the more quickly the driver can step on the breaks and avoid colliding with the pedestrian. The primary goal of this research was to identify situations that lead safer driving (slower and less steering deviation) near critical targets (crosswalks and pedestrians). Of particular interest is the effect of attention and memory on driving performance. Completing other tasks that put a load on attention while driving (e.g., talking on a cell phone) may impair driving performance when there are critical targets to detect (pedestrians). However, this may be minimized when driving in more familiar environments.

Research has shown that when a specific driving route is driven repeatedly, the driving task becomes more automatized and requires (or uses) fewer attentional resources (Charlton & Starkey, 2011, 2013). Charlton and Starkey (2011) found that as drivers drove the same route repeatedly, their speed and lane position became less variable, and they reported that the driving task was easier. Furthermore, Martens and Fox (2007a) found that with repeated drives on a single day, the number of fixations to roadside signs decreased. This suggests that less attention is being allocated to elements of the driving environment as the amount of driving experience within the environment increases. This could lead to an increase in failed target detection or better allocation of attention resources such that more attention is allocated only when the driving situation requires it.

This increased automaticity and decreased allocation of attention to roadside objects may generally be adaptive in an environment that is very consistent across driving experiences. However, what happens if elements of a familiar driving environment require more attention (e.g., emergency evacuations may require driving in a very familiar environment under a very unfamiliar situation)? Although detection of targets that appear consistently (i.e., probable) when driving in the same environment can improve over repeated drives (Charlton & Starkey, 2013), detection of targets that are unexpected (i.e., improbable) declines (Borowsky, et al., 2008; Martens & Fox, 2007b). Response time to a target is quicker when observers know when and where the target will appear (Posner, 1980; Beck, et al., 2014). In addition, observers' expectations about the stability of visual information over time greatly influence their ability to detect a change in the visual world from one glance to the next (Beck, et al., 2004). By measuring participants' eye movements while they completed a detection task, it was discovered that detection failures are largely due to a failure to direct focused attention to the target location (Beck, et al., 2007). Therefore, driving performance in locations where a critical target is expected may vary depending on how familiar drivers are with the driving environment.

In a previous study funded by the Golf Coast Center for Evacuation and Transportation Resiliency, Dr. Justin Ericson and the PI of the current proposal (Dr. Melissa Beck) examined the effects of environmental clutter and cognitive load on the ability to detect a pedestrian entering the roadway (Ericson, et al., 2017). When participants were required to do a task that required a high cognitive load (i.e., tracking the lane changes of two cars on the roadway), they responded more slowly to the pedestrian entering the roadway. Slowed detection of pedestrians may also occur when doing other tasks that increase cognitive load (talking on a cell phone). In the current experiment, we will examine driving performance when drivers are talking versus when drivers are not talking on a cell phone. Further, we will examine driving performance across runs of driving in the same environment. As the driving task becomes more automated (more runs in the same driving environment), the effect of the cognitive load caused by talking on the phone may decline.

Drivers are often distracted by events not directly related to the driving task. For example, it is very common for drivers to engage in conversations with others while driving (e.g., passenger, cell phone), and this can add a cognitive load that can distract attentional resources away from the driving task. In the proposed study, participants will be asked to complete a voicemail message task while driving. This will add a cognitive load to the task that is consistent with a real world driving experience (i.e., is ecologically valid). Much like driving, speech is a behavior that is governed by the availability of cognitive resources. Thus, measuring speech, for example, by using biometric analysis of speech production (e.g., pause duration) and speech signal variability (e.g., emphasis, intonation), can provide important information about the cognitive resources available. Changes in speech production and signal variability have been found in air pilots' speech as flight conditions became more complicated – thus presumably requiring more cognitive resources (e.g. Huttunen, et al., 2011; Simonov & Frolov, 1973). In addition, experimental studies of cognitive load and speech properties have suggested that features of speech reliably change as a function of task complexity (Cohen, et al., 2015; Mendoza, & Carballo, 1998; Cohen, et al., 2012). Furthermore, speech is generally sparser and flatter in individuals with limited cognitive capacity – as a function of neuropsychiatric and neurodegenerative disorders (Cohen & Elvavaag, 2014; Cohen, et al., 2012). Therefore, it is expected that leaving a voice mail will add a cognitive load that could interfere with driving performance.

Talking on a cell phone can impair driving performance, because of a decline in attentional resources allocated to the roadway (Atchley & Dressel, 2004; Stayer & Drews, 2007). Generating speech can disrupt central attention (Kunar, et al., 2008), which could impair driving performance. However, in some cases, verbal tasks can lead to an improvement in driving behavior. Atchley et al. (2014) had participants free associate a word in response to a presented word. This verbal task lead to less steering deviation at the beginning of the drive when it was completed throughout the entire drive, and at the end of a monotonous drive when it was only completed at the end of the drive. When attention is waning, the verbal task can increase alertness or attention to the driving task. However, the verbal task used by Atchley et al., (2014) only required a one word response, and was likely had a lower cognitive load than leaving a voice mail while driving. Therefore, in the current study we examined the effect of a higher cognitive load verbal task (i.e., leaving a voice mail) on driving performance.

The present study tested two hypotheses. First, leaving a voicemail will lead to more erratic driving (increased velocity and steering deviation). Second, when the visual attention load is high, either because the driver is less familiar with the driving environment or there is a critical target (crosswalk) nearby, the effect of leaving a voicemail on driving performance will be greater.

2.0 METHOD

2.1 PARTICIPANTS

Ninety Louisiana State University students were recruited to participate from the psychology pool. Fifteen participants did not complete the experiment resulting in 75 participants total for the experiment. Fourteen participants were unable to complete the experiment due to motion sickness; one participant’s data were lost due to experimenter error. Participants were required to show the experimenter their state issued driver’s license prior to participation.

2.2 DESIGN

The study was a 2 x 2 x 4 x 4 x 2 mixed factorial design. The talking variable and the crosswalk order variables were manipulated between subjects. Participants were assigned to either the silent or talking condition. They were also randomly assigned to have pedestrians be more probable at either the first or second crosswalk. The remaining three variables (run, proximity to crosswalk, and pedestrian probability) were manipulated within subjects. Each participant completed six runs, but only the last four were used for analysis (run 3, run 4, run 5, run 6). Runs 3-6 were segmented into four sections based on proximity to each crosswalk (45-30 meters before, 30-15 meters before, 15-0 meters before, 0-15 meters after). Finally, each run had two crosswalks and one had a high probability of having a pedestrian present, and the other had a low probability of having a pedestrian present (pedestrian probable, pedestrian improbable).

2.3 APPARATUS AND STIMULI

To simulate a driving environment, the study was conducted using the Louisiana State University driving simulator manufactured by Realtime Technology, Inc (see Figures 1 and 2). The simulator is a full-size Ford Focus that is mounted without wheels surrounded by three projection screens in the front and one screen in the back. The virtual environment is also projected on the side mirrors to produce a high fidelity virtual environment. The virtual environments were created using the Internet Scene Assembler and SimVista control interface was used to run the environments and collect the data.

An Olympus digital voice recorder collected voice data while the participants left their voice messages while driving. A headset was worn by the participants that had a microphone that was attached to the right headphone.

The driving course was the same for all six runs. It contained a four-lane road (two-lanes on each side of a midline) lined with buildings and trees (see Figures 2 and 3). The driving environment appeared to be a sunny data at noon, with the sun high in the sky and no shadows visible. The driving course started with a straight away leading into an S-curve. Coming out of the S-curve, the course entered another straight away that contained two four-way intersections. The intersections did not contain cross traffic, stop signs, or signals to allow a constant driving speed. A flagpole indicated that the trial was coming to an end. Participants stopped at a stop sign at a T-intersection that triggered the end of the program. The first crosswalk was 75 meters before the first four-way intersection. The second crosswalk appeared 75 meters after the second four-way intersection. The entire course was 975 meters long.

In the talking condition, driving the car triggered a tone 50 meters before the S-cure and a car honk 15 meters before the stop sign. Participants were instructed that the tone signaled them to start talking about the voicemail prompt topic and that the car honk signaled them to stop talking. The car honk also signaled that participants were approaching the end of the course and the computer program would terminate soon. In the silent condition, participants were only instructed with regards to what the car honk signal.

During the two practice runs, no pedestrians appeared in the virtual environment. Starting with the first test run (run 3), pedestrians could be seen walking along the sidewalks. Half of the participants were assigned to the "crosswalk one" condition in which a woman in a white shirt and jeans was standing with two male pedestrians at the first crosswalk. The woman would cross at the crosswalk in front of the driver for runs 3 through 5. One male pedestrian could be seen standing at crosswalk two, but did not cross the street. On run 6, the crosswalks were switched such that the woman was now positioned at the second crosswalk and walked across the street, and two pedestrians stood at the first crosswalk and did not enter the road. For the "crosswalk two" condition, this pattern was reversed for the first and second crosswalk (the woman crossing the street was at the second crosswalk for runs 3-5 and the first crosswalk for run 6). In both crosswalk order conditions, the crosswalk with a pedestrian entering the road way for runs 3-5 was considered the “probable crosswalk” because there was a higher probability of a pedestrian entering the roadway for that crosswalk. The other crosswalk was considered the “improbable crosswalk”.

2.4 PROCEDURE

Participants presented a valid state-issued drivers licensee and provided informed consent before being familiarized with the driving simulator. All instructions were read aloud to the participants. The first set of instructions familiarized the participants with the simulator by pointing out the car features and set-up. All participants were informed that they could not use the radio while driving. The participants were informed that they would be driving the car six times and that there will be time for a break between each run. Participants were also informed that the driving simulator can cause motion sickness and that they are able to withdraw at any point. Next participants were instructed to enter the car and notice the red button that would allow them to end the simulator immediately at any point. The experimenter addressed any questions before instructing the participant to adjust the seat to match how they normally drive a car. In the talking condition, after the participant adjusted their seat, the participant was instructed to put on the headset.

Following being familiarized with the car, participants completed two practice runs. During the practice runs no pedestrians appeared on the sidewalks and no pedestrians crossed the street. None of the participants left a voicemail during the first practice run. Starting with the second practice run, participants in the talking condition began to talk while driving.

Before the first practice run (run 1), participants were informed they would be driving through the virtual environment to familiarize themselves with how the car functions. The participants were instructed to drive in the right-hand lane and maintain the car’s speed between 30 to 35 miles per hour. A warning was given that they should start to slow down once they approach the flagpole (signaling the end of the run), to stop at the stop sign, and to not put the car in park because this would cause the program would end. The same instructions were given before the second practice run (run 2), except participants in the talking condition were also informed that they were going to practice leaving a voicemail while driving.

In the talking condition, instructions were as follows regarding how to leave a voicemail while driving. Participants were instructed to tell us as much as possible about a particular topic, anything they could think of that related to the topic including some suggestions and when they could not think of anything else to say to start talking about another instance that matched the topic. Participants were reminded again they would be talking each time they drove the car, to maintain their speed between 30 and 35 miles per hour and to stay in the right lane. Finally, participants were asked “Before we start, what is the topic you will be discussing on the voicemail message?” as a check. One of five different topics was discussed on each run through the environment. On each run, participants were asked to discuss either (1) social activities with family and friends, (2) places they want to travel and why, (3) something recently read on social media, blogs or watched on youtube or video blog, (4) courses currently enrolled, and (5) recent movies or tv shows or books. The prompt orders were counterbalanced so each prompted was used once in position in the order. The only difference for the silent condition instructions is participants were never told to leave a voice mail while driving.

3.0 RESULTS

We examined driving velocity and steering deviation across runs through the environment to see how driving performance changed as participants became more familiar with the environment. We focused our analysis on the last four runs (runs 3-6). We also examined driving velocity and steering deviation at different proximities to the cross walks to see if proximity to a local driving event that requires attentional resources (a crosswalk) would impact he effect of talking on a cell phone on driving.

For both dependent measures, we ran a 2 x 4 x 4 x 2 x 2 mixed modal analysis of variance with talking (silent, talking) as a between subjects factor, run (run 3, run 4, run 5, run 6) as a within subjects factor, proximity to the crosswalk (45-30 meters before, 30-15 meters before, 15-0 meters before, 0-15 meters after) as a within subjects factor, crosswalk order (crosswalk one, crosswalk two) was a between subjects variable, and cross walk probability (pedestrian probable, pedestrian improbable) was a within subjects variable. Crosswalk order and crosswalk probability did not have significant effects for either dependent variable, so results pertaining to these factors are not reported below.

For steering deviation, there was a main effect of talking, $F(1, 71) = 9.96$, $p = .002$. There was also a main effect of talking for velocity, $F(1, 71) = 9.18$, $p = .003$. Therefore, overall, leaving a voicemail increased steering deviation and driving velocity

To examine the effect of talking with familiarity with the environment, we examined the effect of run and its interaction with talking. For steering deviation, there was no main effect of run, $F(3, 213) = 1.71$, $p = .17$, but there was an interaction between run and talking, $F(3, 213) = 3.36$ (see Figure 4), $p = .027$. For velocity there was also no main effect of run, $F(3, 213) = 1.8$, $p = .15$, but there was an interaction between run and talking, $F(3, 213) = 9.72$, $p < .001$ (see Figure 5). For both steering deviation and velocity, the effect of talking decreased as the number of runs through the driving environment increased.

To examine the effect of talking with the added attentional demand of approaching a crosswalk, we examined the effect of run and its interaction with proximity to the crosswalk. For steering deviation, there was a main effect of proximity to the crosswalk, $F(3, 213) = 90.53$, $p < .001$, and an interaction between proximity to the crosswalk and talking, $F(3, 213) = 5.95$, $p = .049$ (see Figure 6). For velocity there was also a main effect of proximity to the crosswalk, $F(3, 213) = 186.7$, $p < .001$, and an interaction between proximity to the crosswalk and talking, $F(3, 213) = 4.23$, $p = .006$ (see Figure 7). For both steering deviation and velocity, the effect of talking increased when the driver was closer to the crosswalk.

4.0 DISCUSSION

This study demonstrates that there is an effect of talking on a cell phone on driving performance. Participants left voicemails on various topics while driving in a driving simulator. Drivers who were leaving a voicemail drove faster and had more steering deviation than drivers not leaving voicemails. In addition, these effects were largest near pedestrian crosswalks and decreased as drivers became more familiar with the driving environment. This suggests that talking on the cell phone can be most detrimental to driving safety when driving in an unfamiliar environment and when extra attention is needed for detecting important elements in the driving environment (e.g., pedestrians).

These findings can be used to (1) guide driving laws, specifically laws about talking on cell phones while driving, and (2) design of safety alerts on cell phones and cars. Laws about talking on cell phones could be enforced or stricter during driving situations that require a high level of attention (e.g., driving in the city during traffic versus driving in a rural low traffic environment). Furthermore, cellphones could be equipped with warnings that would be triggered when a driver was talking on the cell phone in high traffic or otherwise attentionally demanding driving environments (e.g., construction zones).

5.0 FIGURES

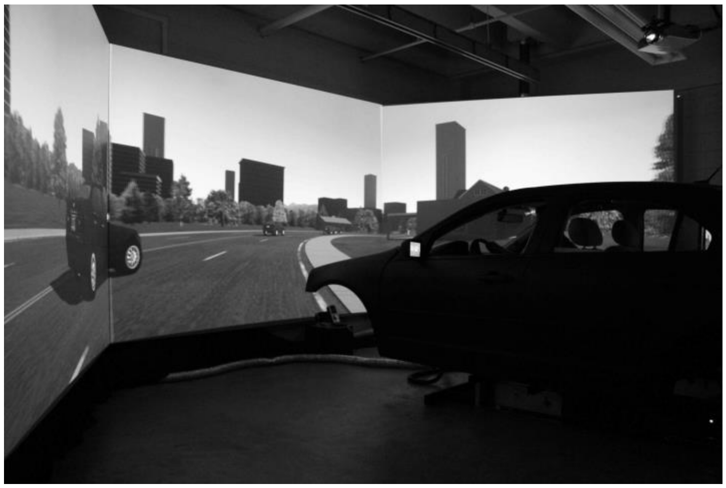

Figure 1: View of Realtime Technologies Inc. Driving simulator from outside of the car.

Figure 2: View of Realtime Technologies Inc. Driving simulator from inside of the car.

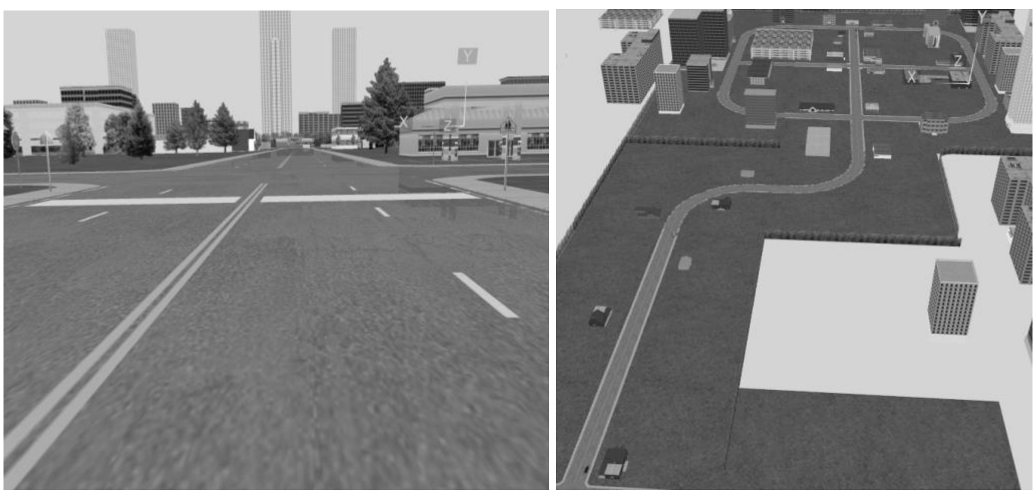

Figure 3: View of Realtime Technologies Inc. Driving simulator view of one of the crosswalks (left picture) and aerial view of the driving course (right picture).

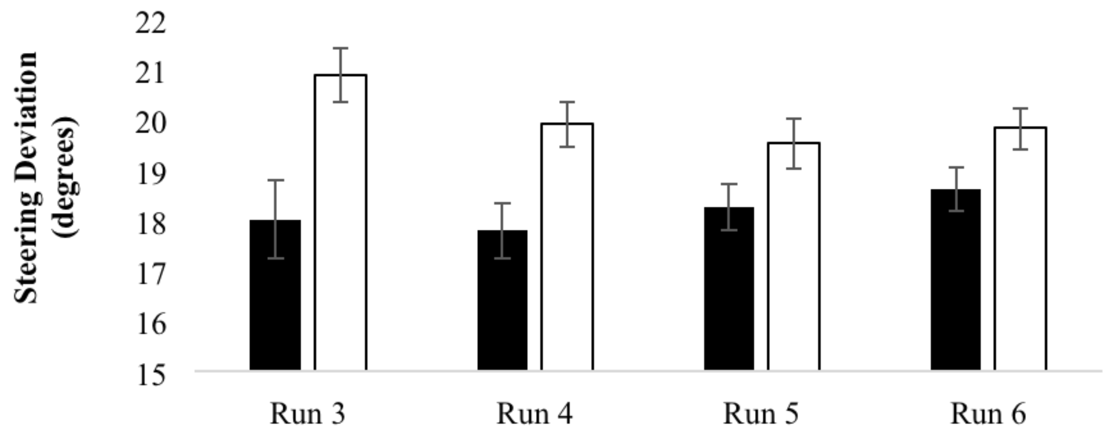

Figure 4: Steering deviation for talking (white bars) and silent (black bars) conditions across runs 3-6.

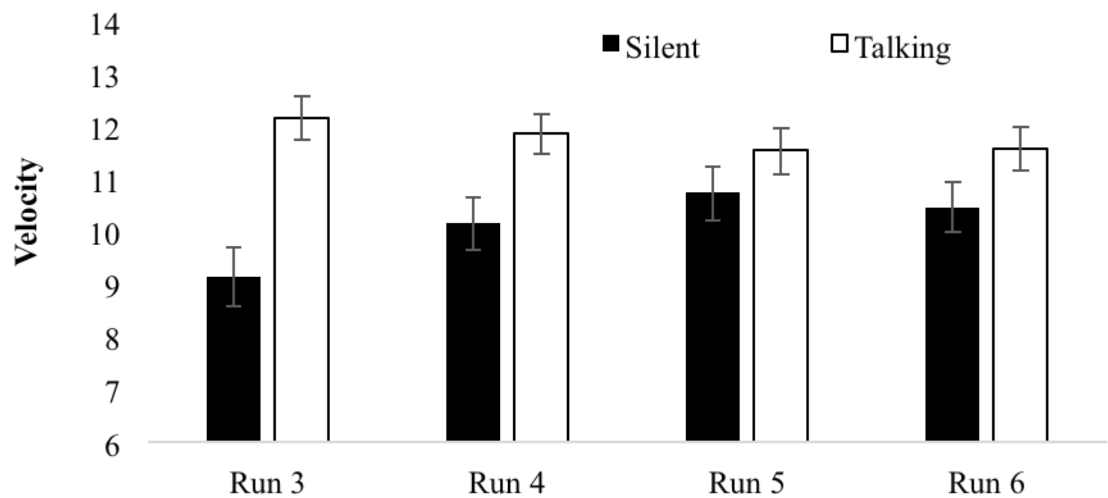

Figure 5: Velocity for talking (white bars) and silent (black bars) conditions across runs 3-6.

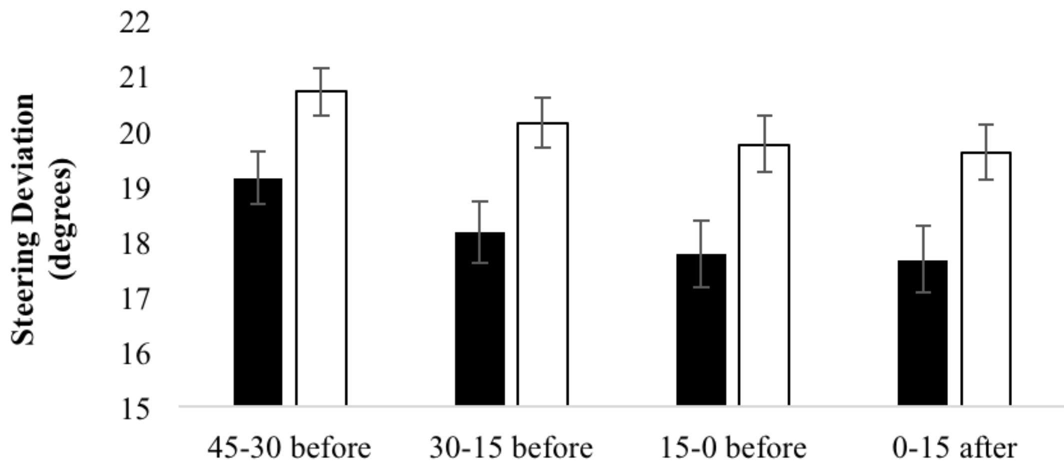

Figure 6: Steering deviation for the talking (white bars) and silent (black bars) conditions across road segments designated by meters from the crosswalks.

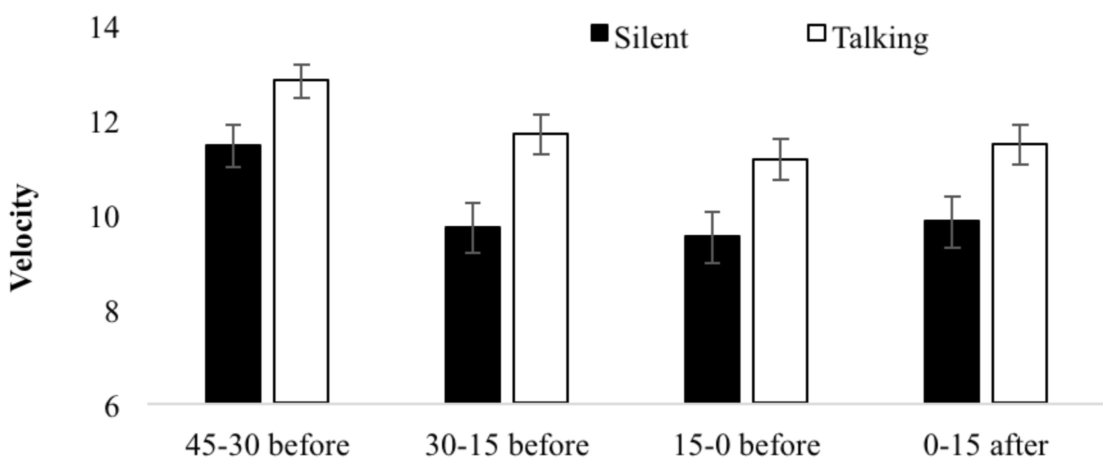

Figure 7: Velocity for the talking (white bars) and silent (black bars) conditions across road segments designated by meters from the crosswalks.

6.0 REFERENCES

Atchley, P., & Dressel, J. (2004). Conversation limits the functional field of view. *Human Factors*, *46*, 664–673.

Beck, M. R., Angelone, B.A., & Levin, D. T. (2004). Knowledge about the probability of change affects change detection performance. *Journal of Experimental Psychology: Human Perception and Performance*, *30*(4), 778-791.

Beck, M.R., Hong, L.S., van Lamsweerde, A.E., & Ericson, J.M. (2014). The effects of incidentally learned temporal and spatial predictability on response time and visual fixations during target detection and discrimination. *PLoS One, 9*(4): e94539. doi:10.1371/journal.pone.0094539

Beck, M.R., Peterson, M.S., & Angelone, B.A. (2007). The roles of encoding, retrieval, and awareness in change detection. *Memory and Cognition, 35*(4), 610-620.

Borowsky, A., Shinar, D., & Parmet, Y. (2008). Sign location, sign recognition, and driver expectancies. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*, 459–465.

Charlton, S. G., & Starkey, N. J. (2011). Driving without awareness: The effects of practice and automaticity on attention and driving. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*, 456–471.

Charlton, S. G., & Starkey, N. J. (2013). Driving on familiar roads: Automaticity and inattention blindness. *Transportation Research Part F: Traffic Psychology and Behaviour*, 121-133.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*, 87–185.

Cohen, A. S., Elvevaag, B. (2014). Automated computerized analysis of speech in psychiatric disorders. *Current Opinion in Psychiatry*.

Cohen, A. S., Dinzeo, T J., Donovan, N J., Brown, C. E., & Morrison, S C. (2015) Vocal acoustic analysis as a biometric indicator of information processing: Implications for neurological and psychiatric disorders, Psychiatry Research 226(1), p. 235-241, NIH Public Access, pubmed, doi:10.1016/j.psychres.2014.12.054

Cohen, A. S. Morrison, S, Brown, L. A., Minor, K. M (2012). Towards a cognitive resource limitations model of diminished expressivity in schizotypy. *Journal of Abnormal Psychology*. 121-1.

Ericson, J.E., Parr, S.A., Beck, M.R., & Wolshon, B (2017). Compensating for Failed Attention while Driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 65-74.

Huttunen, K., Keranen, H., Vayrynen, E., Paakkonen, R., & Leino, T. (2011). Effect of cognitive load on speech prosody in aviation: Evidence from military simulator flights. *Applied Ergonomics, 42*(2), 348-357. doi: 10.1016/j.apergo.2010.08.005

Kunar, M. A., Carter, R., Cohen, M., & Horowitz, T. S. (2008). Telephone conversation impairs sustained visual attention via a central bottleneck. *Psychonomic Bulletin & Review, 15*, 1135–1140.

Martens, M. H., & Fox, M. (2007a). Does road familiarity change eye fixations? A comparison between watching a video and real driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(1), 33–47.

Martens, M. H., & Fox, M. R. J. (2007b). Do familiarity and expectations change perception? Drivers glances and response to changes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10,* 476–492.

Mendoza, E., & Carballo, G. (1998). Acoustic analysis of induced vocal stress by means of cognitive workload tasks. *Journal of Voice*, *12*(3), 263-273.

Öztekin, I., Davachi, L., &McElree, B. (2010). Are representations in working memory distinct from representations in long-term memory? Neural evidence in support of a single store. *Psychological Science*, doi:10.1177/0956797610376651

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. Perception, 28, 1059-1074.

Simonov, P. V., & Frolov, M. V. (1973). Utilization of human voice for estimation of man's emotional stress and state of attention. *Aerospace Medicine*, *44*(3), 256-258.

Strayer, D. L., & Drews, F. A. (2007). Cell phone induced driver distraction. *Current Directions in Psychological Science, 16*, 128–131.