Louisiana Transportation Research Center

Final Report 530

Distracted Driving and Associated Crash Risks

by

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1. Report No. **FHWA/LA.14/530**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle **Distracted Driving and Associated Crash Risks**	**5. Report Date** October 2014 **6. Performing Organization Code** **LTRC Project Number: 13-1SA** **State Project Number: 30000760**	
7. Author(s) Sherif Ishak, Julius Codjoe, Raju Thapa, Kevin McCarter	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address **Department of Civil and Environmental Engineering** **Louisiana State University** **Baton Rouge, LA 70803**	**10. Work Unit No.** **11. Contract or Grant No.**	
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas A&M Transportation Institute Texas A&M University System 3135 TAMU College Station, Texas 77843-135 Louisiana Department of Transportation and Development P.O. Box 94245 Baton Rouge, LA 70804-9245	**13. Type of Report and Period Covered** Final Report, 07/01/12 – 03/31/14 **14. Sponsoring Agency Code**	
15. Supplementary Notes **Conducted in Cooperation with the U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), Federal Highway Administration**		

16. Abstract

Distracted driving is a dangerous epidemic that has resulted in deaths and injuries in crashes throughout the U.S. Research is needed to understand whether common cognitive tasks such as texting, handheld cell phone conversation, and front-seat passenger conversation cause distracted driving and also increase the risk of crashing. The acquisition of the LSU driving simulator offered opportunity for experimental work to be undertaken in this field of research. Sixty-seven participants from the LSU community of students and staff members, DOTD staff, and the general public participated in the experimental work. Participants were placed in simulated environments while being exposed to different tasks (handheld cell phone conversation, texting, and front-seat passenger conversation) to determine the effect on their driving task. Using Lane Position Variability and Mean Velocity to respectively represent lateral and longitudinal control of the vehicle, the results suggest that there was no significant decrease in driver performance during the cell phone conversation. On the contrary, during the texting event, a significant decrease in driving performance was observed in both lateral and longitudinal control of the vehicle. Front-seat passenger task produced significant decrease in the lateral control of the vehicle but not in its longitudinal control. The results also suggest that even though participants maintained longitudinal control of the vehicle during the handheld phone and passenger conversation drives, they significantly slowed their speeds in the process. However for the texting drive, even though they significantly slowed down, the participants still exhibited loss of longitudinal control of the vehicle. The findings of this study have safety and policy implications in the campaign to reduce distracted driving.

17. Key Words Human Factors, Driver Distraction, Crash Risk, Roadway Safety.		**18. Distribution Statement** **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.**	
19. Security Classif. (of this report) not applicable	**20. Security Classif. (of this page)** not applicable	**21. No. of Pages** 44	22. Amount

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LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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LTRC Project No. 13-1SA
State Project No. 30000760

conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center
Southwest Region University Transportation Center (SWUTC)

October 2014

ABSTRACT

Distracted driving is a dangerous epidemic that has resulted in deaths and injuries in crashes throughout the U.S. Research is needed to understand whether common cognitive tasks such as texting, handheld cell phone conversation, and front-seat passenger conversation cause distracted driving and also increase the risk of crashing. The acquisition of the LSU driving simulator offered an opportunity for experimental work to be undertaken in this field of research. Sixty-seven participants from the LSU community of students and staff members, DOTD staff, and the general public participated in the experimental work. Participants were placed in simulated environments while being exposed to differing tasks (handheld cell phone conversation, texting, and front-seat passenger conversation) to determine the effect on their driving task. Using Lane Position Variability and Mean Velocity to respectively represent lateral and longitudinal control of the vehicle, the results suggest that there was no significant decrease in driver performance during the cell phone conversation. On the contrary, during the texting event, a significant decrease in driver performance was observed in both the lateral and longitudinal control of the vehicle. The front-seat passenger task produced a significant decrease in the lateral control of the vehicle but not in its longitudinal control. The results also suggest that even though participants maintained longitudinal control of the vehicle during the handheld phone and passenger conversation drives, they significantly slowed their speeds in the process. However for the texting drive, even though they significantly slowed down, the participants still exhibited loss of longitudinal control of the vehicle. The findings of this study have safety and policy implications in the fight to reduce distracted driving.

ACKNOWLEDGMENTS

This project was completed with support from the Louisiana Department of Transportation and Development (DOTD), Southwest Region University Transportation Center (SWUTC), the University Transportation Centers (UTC), and the Louisiana Transportation Research Center (LTRC). The research team also gratefully acknowledges the assistance received from the Project Review Committee (PRC) members for their valuable feedback and all other DOTD personnel involved during the course of this project.

IMPLEMENTATION STATEMENT

Factors affecting the cognitive tasks associated with driving are increasingly becoming critical to the overall roadway safety performance. Therefore, more research is needed in order to understand the complexity and the impact of distraction on driving behavior. Such distractions are likely to affect the driving performance and, consequently, elevate crash risk. As such, there is a dire need to understand the prevalence of driver distractions in conjunction with crashes and near-crashes. Research is needed to better understand distracted driving and the factors that elevate crash risk for cognitive tasks such as cell phone talking, texting, eating, reading, etc.

The acquisition of a driving simulator at LSU provides ample research opportunities for conducting research in the area of human factors, and particularly in driver distraction. This report presents findings of a study that utilized the driving simulator on the LSU campus to measure the risks associated with various distractions faced by the driving population. Participants were placed in simulated environments while being exposed to differing driver distractions to determine the effect on their driving task. The findings of this study will assist highway safety professionals in developing behavioral strategies to mitigate crashes due to distracted driving. It will also allow for the development of public awareness and education programs specifically targeting distracted driving. Additionally, it will provide information to elected officials and inform decision makers on matters related to distracted driving.

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INTRODUCTION

Distracted driving can be defined as any activity that takes the driver's attention away from the primary task of driving, thereby increasing the risk of driver error, near misses, and crash involvement. They can include physical tasks (e.g., eating, adjusting entertainment systems, or personal grooming); auditory or visual diversions (e.g., a crying baby, talking to passengers, or watching an off-road activity); or cognitive activities (e.g., talking on a cell phone, operating a navigation system, or reading materials). With the inevitable development of new in-vehicle systems (IVS) aimed at making in-vehicle communication less tasking and purported to increase road safety, distracted driving will be on the rise as drivers share their attention with these IVS. However, due to the different driving styles and different innate qualities of people, a distraction could impact driving behavior of one driver and yet have no effect on another.

Over the past decade, a number of bodies, including government agencies, traffic safety advocacy groups, and law enforcement agencies, have successfully increased public awareness level of the traffic safety risks from distracted driving. However, lack of substantial crash data with adequate reporting tools on distracted driving causes, means the underlying statistics from police-reported distracted driving crashes could be misleading. More scientific knowledge of distraction related crashes is required and a number of agencies are currently funding targeted researches in this discipline. The acquisition of a driving simulator at LSU has provided research opportunities for conducting research in the area of driver distraction. This study therefore utilizes the driving simulator at LSU to measure the risks associated with three distractions that are routinely faced by the driving population, namely: handheld phone conversation, texting, and front-seat passenger conversation.

Currently in Louisiana, drivers within their first year of licensure and commercial and bus drivers are banned from all forms of cell phone use while drivers with a learner's permit are banned from using only handheld cell phone use. All other drivers are allowed to have handheld or hands-free cell phone conversations, as well as front-seat passenger conversation. Texting is banned for all drivers.

This report presents details of the entire research effort in using the LSU driving simulator to investigate the crash risks associated with these activities. It provides an overview of related studies before giving a detailed description of the investigation and how the results affect the current Louisiana laws on distracted driving.

OBJECTIVES

The main goal of this research was to utilize a driving simulator to measure the risks associated with various distractions faced by the driving population. This was achieved through the following:

1. Conducting a thorough literature review on driver distraction and roadway safety, including the cause and extent of distraction associated with driving tasks.
2. Identifying a set of cognitive tasks that are believed to have the most impact on driver distraction.
3. Establishing a set of performance measures for the type and level of distraction based on the driving behavior.
4. Designing and conducting simulation experiments involving a sample of human subjects.
5. Comparing using appropriate statistical techniques the driving behavior of the human subjects with and without the identified distraction factors.
6. Analyzing the results and making conclusions.

SCOPE

The scope of this study was limited to the use of the driving simulator at LSU to measure the level of driver distraction. Experimental work was conducted with the simulator using human subjects as drivers. Volunteers were sought from the LSU community of students and staff members, DOTD staff, and the general public to participate in the experimental work. No monetary compensation was provided for participants.

METHODOLOGY

Background

The concept of distracted driving and associated crash risks has long been acknowledged as a significant road safety concern across the globe (Regan, Lee and Young, 2008) and various studies have focused on this concern over the last two decades. Even so, drivers continue to engage in distracting non-driving related activities. Such activities can be classified under three main types: visual, cognitive, and physical distraction. All these types of distraction have been acknowledged to negatively affect driver performance and thus, increase the risks of associated crashes and near-misses (Amditis et al., 2010). Driver performance is affected in the following areas: reduced lateral and longitudinal control, with effects being more pronounced in older drivers (Reed and Green, 1999; Engstrom, Johansson and Ostlund, 2005; Rakauskas, Gugerty and Ward, 2004; Strayer, Cooper and Drews, 2004); reduced situation awareness (Kass, Cole and Stanny, 2007); and slower response times of up to 50% to roadway hazards (Sussman et al., 1985). It is therefore not surprising that in 2011, the National Safety Council estimated that 23% of all motor vehicle crashes each year – or 1.3 million – involved drivers talking or texting on cell phones.

With the rapid advancement in human-in-the-loop simulation technologies, along with the continuous decrease in their cost, driving simulators have recently attracted the attention of researchers in the area of transportation engineering. Driving simulators have repeatedly proven their potential use in a variety of applications that can substantially improve traffic operation and safety (Bella, 2009). Providing a safe, inexpensive alternative to conventional experimentation, driving simulators have advantages in terms of experimental control and data collection.

The following sub-sections give a brief literature review of the problems of distracted driving, discusses the benefits of using driving simulators for related experiments, and presents a brief overview of previous work related to this study. This is followed by the methodology section where a description of the experiment undertaken for this study is presented. The results are then presented in the discussion of results section, and are followed by the conclusion and recommendations.

The Problem of Distracted Driving

Significant changes in data coding in the Fatality Analysis Reporting System (FARS) proposed by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) in 2010 means the fatal crash data can now be more focused on the set of distractions most likely to affect the crash. Prior to 2010, FARS was more general and the only way to tell a driver was distracted was to combine specific behaviors of the driver. For this reason, NHTSA's distracted driving statistics from police reported crashes that have been well publicized and used in public awareness campaigns may not be credible after all. All statistics from FARS pertaining to this research will therefore be limited to the year 2010 and beyond.

According to a NHTSA report in September 2012 (Research Note DOT HS 811650), in 2010, 2,843 crashes (9%) involved driver distraction, killing 3,092 people (9%) and injuring an estimated 416,000 people (19% of all the injured people). Out of these fatal crashes, 408 people (13%) had cell phones as the cause of distraction. According to the report, 53% of drivers who routinely engage in talking on their cell phone while driving were under the age of 30, an overrepresentation when compared to drivers overall. Research (NHTSA Research Note DOT HS 811611) also shows that drivers under the age of 24 are 44% to 49% more likely to text than older drivers. With CTIA-The Wireless Association reporting that 2.3 trillion voice minutes were made and 2.2 trillion text messages were sent in the US in the year 2012, and 40% of all American teens saying they have been in a car when the driver used a cell phone in a way that put people in danger (Madden and Lenhart, 2009), it is no wonder that cell phones have attracted the most attention of the various distracters. In fact, the 100-Car Study (NHTSA Research Note DOT HS 810593) found out that the use of handheld wireless devices (primarily cell phones and a small amount of PDA) did not only have the highest frequency of secondary task inattention-related activities, but were also associated with the highest frequencies of crashes, minor collisions, near crashes, and number of incidents. However, there are many other in-vehicle and external sources of driver distraction that can be equally dangerous.

Public perception is that current laws on distracted driving have not been effective deterrents, and sometimes are even confusing as there is not a single consistent law for all U.S. states. Only 12 states (excluding Louisiana) out of the 50 US states prohibit all drivers from using handheld cell phones while driving but 41 states (including Louisiana) prohibit text messaging for all drivers. No state, however, bans all types of cell phone use (messaging, handheld and hands-free) for all its drivers (Distraction.gov). On the contrary, many others also feel that with the rapid advancement of portable and in-vehicle devices, drivers can multi-task and not pose safety risks on the road. Automobile manufacturers constantly out-do each other with the level of sophistication of new in-vehicle gadgets and market these as safer alternatives to the more common distracters such as cell phone talking. People now feel an intrinsic need to use the perceived idle time during driving more productively, and are therefore embracing these new in-vehicle gadgets as well as normal cell phone use to maintain connectivity to others at all times. Consequently, the problem of distracted driving now goes beyond driving issues to lifestyle issues.

It is now obvious that legislation alone will not effectively combat the problem of distracted driving. The U.S. Department of Transportation's (DOT) 'Blueprint for Ending Distracted Driving' (NHTSA Research Note DOT 64-12) outlines a comprehensive strategy to address this issue, including legislation, co-operative government-auto industry efforts, education programs to reach out to novice drivers, and a national public awareness campaign to change public attitudes toward distracted driving.

The Use of the Driving Simulator

Experiments involving distracted driving can be investigated under three settings: in a driving simulator, in an instrumented vehicle, or in circumstances involving neither where isolated elements of the driving task are replicated; e.g., reaction times. Because findings of the experiments are meant to be applied to drivers in the real world, it is imperative that the settings be as close to the actual driving environment as possible. For this reason, the third setting can be deemed as least favorable but the use of driving simulators or instrumented vehicles for related experiments remains an interesting topic among researchers.

Experiments in instrumented vehicles are experiments in real cars that have been fitted with sensors and other data collection gadgets, which tend to be rather invasive and are usually add-ons to the normal IVS a vehicle will normally be equipped with. Driving in instrumented vehicles can take place in controlled settings such us on a specific test track or closed circuit, or in real traffic environment such as undertaken during the 100-Car Study (NHTSA Research Note DOT HS 810593). Even though such experiments will produce more realistic scenarios, and thereby more valuable data to study driver behavior and performance, the collection of data could be problematic. Test vehicles will have to be fitted with the data acquisition system, a very expensive procedure, which means very few instrumented vehicles have been developed to be used in research. An example is the UTDrive (Angkititrakul et al., 2007), a 2006 Toyota RAV4 equipped with brake and gas pedal pressure sensors, distance sensors, GPS, hands-free car kit, heart-rate and blood pressure measuring devices, cameras, microphone, and link to the Controller Area Network (CAN) signal to allow collection of steering wheel angle, vehicle speed, engine speed and vehicle acceleration. Other examples are the Argos (Perez et al., 2010) and UYANIK (Abut et al., 2009).

On the other hand, experiments in driving simulators are easier to control and data collection is relatively easier and non-invasive since vehicles are designed with the data acquisition component in mind from the onset. They provide an inexpensive alternative to conventional experiments and sometimes impossible (unethical or safety implications) field tests that cannot be achieved in real life situations (Kaptein, Theeuwes and Van der Horst, 1996). Nevertheless, the controlled settings and environments provide a lesser degree of realism than an instrumented vehicle would. The fidelity of the simulator defines its ability to replicate real life scenarios, and therefore, the higher the fidelity, the closer the simulator is to the real world. However, for research, the choice of the right type of simulator depends on what needs to be accomplished and whether its fidelity can best meet the research objectives. A simulator can have a high fidelity for one feature (e.g. visuals) and low fidelity for another feature (e.g. motion and vibration). For driver distraction experiments, a medium or higher fidelity simulator is required for the performance variables being collected. This is because experiments must be close to real life situations for any meaningful observations to be made.

Perhaps the most extensive studies to date on the issue of which driver setting is the most appropriate to use is the 100-paper review undertaken by Bach et al, 2009. In their study of driver inattention due to IVS, they found that 37% involved instrumented vehicles, 52% involved driving simulators, and the remainder 16% involved neither. They classified attention measures into five categories: primary task performance, secondary task performance, eye glance behavior, physiological measurements, and subjective assessments. Table 1 below, which is adapted from their study, provides more information on each category and indicates which driver setting was used for the investigation.

The numbers refer to the percentage of experiments with that particular driver setting carried out for the specified classification measures; e.g., 73% of experiments measuring lateral control were undertaken using a driving simulator. Primary task relates to aspect of vehicle control; secondary task relates to tasks involving manipulation of an IVS while driving; eye glance behavior pertains to visual attention; physiological measurements refer to stress levels and attention capacity resulting from tasks; and subjective assessments relates to participants' perception of the tasks attributes.

The summary indicates that the 'neither' scenario was mainly used for tests involving reaction times, where it is easier to imitate driver reaction times without the use of vehicles. For instance, test subjects could be asked to press a buzzer in response to a cue as a measure of their attentiveness. For all other categories, the ‘neither’ scenario did not seem suitable. However, all the tests could be done with either the driving simulator or the instrumented vehicle, and with the exception of two classification measures, more tests were carried out with the driving simulator.

The argument therefore remains whether the added element of realism in an instrumented vehicle over a driving simulator experiments justifies the problems associated with this type of driver setting. Whether the future will see a major shift to instrumented vehicles or driving simulators remains to be seen. Nevertheless, the possibility of both driver settings becoming obsolete is not to be dismissed as the acceptance of ‘driverless cars,’ which eliminates the human factor in driving, gains momentum in today’s society.

Table 1
Driver settings for distracted driving experiments

	Classification of Measure	**Driving Simulator (50%)**	**Instrumented Vehicle (35%)**	**Neither Scenario (15%)**
Primary Task (41%)	Lateral Control (14%)	73	24	2
	Longitudinal Control (12%)	54	43	3
	Car Following Performance (5%)	75	25	0
	Driver Reaction (10%)	50	30	20
Secondary Task (22%)	Task Effectiveness (15%)	48	36	16
	Task Efficiency (7%)	48	43	10
Eye Glance Behavior (24%)	Eye Glance Frequency (9%)	50	43	7
	Eye Glance Duration (9%)	48	33	19
	Eye Scanning Patterns (5%)	31	56	13
	Physiological Measurements (3%)	40	60	0
	Subjective Assessments (10%)	50	43	7

Overview of Recent Studies on Distracted Driving

This section provides a brief overview of recent research efforts on distracted driving that utilized a driving simulator, with the intention to inform and guide this research's understanding of current practices and limitations. Table 2 provides a summary of selected studies undertaken within the past few years, from 2006 to 2012; it should be noted this list is not a comprehensive list of all recent research in this discipline. All the experiments in this review were undertaken in a driving simulator whose features, important for the collection of the performance variables, were at medium or high fidelity.

Table 2
Summary of recent studies on distracted driving using a driving simulator

Reference	Performance Measure	Task	Participants	Statistical Approach
Hughes et al., 2012	Speed Speed variability Lane position variability Percent dwell time NASA-Task Load Index	music and singing	n = 21 mean age = 35 yrs	ANOVA
Holland & Rathod, 2012	Pedestrian collision Vehicle collision Speed exceeded Theory of planned behavior questionnaire	mobile phone call tones	n = 27 18 - 29 yrs	ANOVA
Schwebel et al, 2012	Time left to spare Look left and right Look away Vehicle-Pedestrian collision Demographic, "Walking Diary", Media use questionnaire	mobile phone use and listening to music effect on pedestrian safety	n = 138 17 - 45 yrs	Logistic Regression
Kaber et al, 2012	Variable flow pattern Eyes-off-road-time Speed	vehicle passing and following task Also looking for target and deciphering audible message (visual, cognitive and adaptive behaviour tasks)	n = 21 16 - 21 yrs	ANOVA
Kircher & Ahlstrom, 2012	Speed Speed variability Lane position variability Standard deviation of lateral position	response to tunnel design with or without secondary tasks (visual and cognitive tasks, where drivers had to interact with the standardized visuo-manual divided attention)	n = 28 mean age = 41.3 yrs	Generalised linear model (GLM)
Devlin et al, 2012	Speed Number of braking application Brake Response Time (BRT)	cognitive (response to stop sign, signal controlled intersection, and critical light change at controlled intersection)	n = 28 65 - 87 yrs	ANOVA
Rudin-Brown et al, 2012	Speed Speed variability Standard deviation of lateral position (SDLP) Total gaze time NASA-Raw Task Load Index	mobile phone use including audio task	n = 24 25 - 50 yrs	ANOVA
Rouzikhah et al, 2012	Lane position variability Brake response time (BRT) modified NASA-Task Load Index	eco-driving message task, CD changing task, entering a five digit number in a PDA task, and a baseline task, (manual, cognitive, visual and auditory tasks)	n = 22 18 - 66 yrs	ANOVA

Reference	Performance Measure	Task	Participants	Statistical Approach
Horberry et al, 2006	Speed Speed variability NASA - Task Load Index	effect of visual clutter (out-vehicle) operating vehicle entertainment system and simulating hands-free mobile phone conversation (in-vehicle)	n = 31 mean age = 21yrs(young) mean age = 37yrs (mid-age) mean age = 66yrs(old)	ANOVA
Chattington et al, 2009	Standard deviation of lateral position (SDLP) Speed variability Deceleration rate Brake position Brake speed Subjective questionnaire	advertising conditions	n = 48 mean age = 44.6	ANOVA
Horrey et al, 2009	Brake Response Time (BRT) Pace clock accuracy Lateral positioning	engaging guessing game and simple mental arithmetic tasks Also subjective estimates of demand and performance	n = 41	none stated
Son et al, 2010	Mean forward velocity Speed control Standard deviation of lateral position (SDLP) Physical well-being and driving frequencies questionnaire	n-back auditory delayed recall task	n = 72 and n = 63 (20 - 29yrs and 60 - 69yrs)	Generalised linear model (GLM)
Liang & Lee, 2010	Steering error and SDLP Minumum headway time and BRT Off- road glance duration and frequency Blink frequency Saccade speed Standard deviation of horizontal and vertical fixation positions	listening to audio clip (cognitive) analyzing maps and other visual displays (visual) Also combined cognitive/visual task	n = 16 35 - 55 yrs	ANOVA
Reimer et al, 2010	Speed Coefficient of velocity Total distance driven over the speed limit	Low demand hands-free phone conversation More demanding working memory task	n = 25 young adults with ADHD mean age = 20.56yrs n = 35 controls mean age = 20.65yrs	ANOVA with Benferroni adjustment
He et al, 2011	Mean and Standard deviation of lane position Distance headway Time to contact (TTC) Standard deviation of gaze positioning (both horizontal and vertical)	Effect of mind wandering performing car following tasks	n = 11 females n = 7 males mean age = 22yrs	ANOVA
Garrison, 2011	Lane positioning Steering angle and velocity Number of gaze and mean gaze duration Questionnaire for memory test	simulated hands-free mobile phone conversation task Also recognition and recollection task	n = 18 18 - 42yrs	ANOVA
Briggs et al, 2011	Lane positioning variability Speed variability Heart Rate (HR) Number of fixations Vaariation in fixation patterns Nmuber of variations from normal road rules	telephone conversation on spiders	n = 26 19 - 55yrs	ANOVA
Unal et al, 2012	Speed variability Deceleration rate Brake pedal position Time to Contact Standard Deviation of lane positioning	in-vehicle loud music (90dBA)	n = 69 18 - 31yrs	ANOVA
Prabhakharan et al, 2012	Speed exceedance Self-reported questionnaire	mental arithmetic task.	n = 60 18 - 25yrs	ANOVA

Following on from this review, a number of points were noted and are discussed as follows:

Performance Measures

It was observed that researchers used various performance measures to quantify the effect of the secondary distracting tasks on the participants' attention to the primary task of driving. Table 3 presents a summary of the type of behavior exhibited by participants and the corresponding performance variables that were associated with them. The choice of which performance measures are appropriate entirely depends on the research questions under investigation and it was noted that researchers used combinations that were appropriate for their research needs.

Table 3
Driver behavior and corresponding performance measure

Driver Behavior	Performance Measure
Eye movement	Off-road glance duration and frequency
	Blink frequency
	Standard deviation of horizontal and vertical fixation position
	Mean gaze duration and frequency
Road positioning	Standard deviation of lane position
	Steering error
	Headway or time to contact lead car
	Number of deviations from normal rules of the road
Braking effort	Maximum brake position
	Deceleration rate
	Brake response time
Speed	Mean speed
	Standard deviation from mean speed
	Standard deviation from posted speed limit
	Distance driven over speed limit
	Percentage coefficient of variation of speed

The driving behaviors that were quantified also depended on the researcher's preferences, how best they answered the research objectives, and more importantly, the capability of the driving simulator to collect data that could be used to quantify the specific behavior.

Secondary Tasks

These are the tasks that drivers were asked to undertake in addition to their primary task of driving to ascertain their distracting effect. Distracting effect refers to the quantification of the effect of the secondary task(s) on a driver's driving performance. Several distracting sources were investigated for all the experiments with some repeated through more than one experiment. Most of these sources where internal, where the participant was required to engage in the distracting activity within the confines of the driving simulator; as opposed to external, where the distracting activity was outside the confines of the driving simulator. Again, the choice of secondary tasks to be used in any research depends on the research questions under investigation. Where the focus is on distracted driving in general, it may be prudent to use secondary tasks that are considered very common to the general public and for which most drivers engage in during their daily commutes.

Sample Size

There was no pattern identified on the use of a sample size that would be considered appropriate for each study. Apart from two of the studies that utilized a rather large sample size of 135 and 138, the rest of the studies utilized samples ranging from 16 to 69 with an average of 33 participants per experiment. In practice, the budget for the experiment is likely to dictate the final sample size, but it is widely accepted that a larger sample size is more favorable since that will decrease the amount of sampling error from the results of the experiment. To also increase the generalizability of the research findings on the target population, intentional bias may be introduced into the recruitment process so the sample will be drawn out of a population representing the target group for which the experiment is aimed at; e.g., teen drivers, a metropolitan’s driver population, etc.

Statistical Method

The statistical method used to analyze the data was overwhelmingly Analysis of Variance (ANOVA), which is the traditional tool used in this discipline. Performing ANOVA on each performance variable means undertaking many comparisons if several performance variables were measured for that experiment, as has been the case for most of the past experiments reviewed in this literature. Analyzing multivariate datasets with a univariate method like ANOVA can result in loss of power by not taking into account any correlations between the performance variables. Similarly, using separate univariate analyses in place of a single multivariate analysis can result in an inflated Type I error rate. Both cases may lead to erroneous conclusions and affect the accuracy of the research findings. However, where very few performance measures are analyzed, ANOVA may be more appropriate because of the reduced possibilities of correlations, and the fact that ANOVA is relatively more easy to use and interpret. Also, using multivariate techniques usually require larger sample sizes to enable the analysis to be workable, but this is not a requirement of ANOVA. In both cases, however, smaller sample sizes may result in a decrease in statistical power which is defined as the probability of detecting a significant distracting effect in the sample, given that the distracting effect actually occurs in the population.

Pilot Study

Prior to the main study, a pilot study was initially conducted during November – December 2012, primarily to obtain familiarity with the experimental set-up, test out the route and secondary tasks, test the ease of data collection, undertake a preliminary data analysis for evidence of distraction, and decide on an appropriate statistical technique that will be used for data analysis for the actual study.

Thirteen participants, comprising 4 females and 9 males with age range of 21 – 38 years, participated in the study using the LSU driving simulator. Details of the experimental procedure, apparatus used, data collection, and data analysis is provided within the sub-sections under the main study as they were similar. From the review of recent studies on distracted driving, the following 6 tasks were investigated during the pilot study: manual radio tuning, operating a navigation device, text messaging, engaging in a handheld cell phone conversation, engaging in front-seat passenger conversation, and retrieving a phonebook contact. Following on the analysis of the data resulting from the pilot study, the following conclusions were drawn:

- The research team agreed that subjecting participants to 6 tasks plus a control drive was too demanding and taking too long to complete. Fatigue was setting in and some participants were getting disgruntled. It was decided to reduce the number of tasks to 3 plus a control drive.
- Similar distracting effect was observed between operating a navigation device and text messaging, as well as between manual radio tuning and front-seat passenger conversation. It was decided that operating a navigation device and manual radio tuning should therefore be omitted from the main study and the effect of text messaging and front-seat passenger conversation should be investigated instead.
- The research team agreed to combine the phonebook contact retrieval task with the handheld cell phone conversation task since, in the real world, people performed these tasks in tandem.
- Lane position variability and average velocity were found to be appropriate performance measures to be used to represent lateral and longitudinal control respectively. Distracted driving produced higher lane position variability but lower average velocity.

- ANOVA and T-tests were found to be appropriate statistical techniques for the data analysis because only two performance measures were being analyzed and the sample size utilized was quite low.

Main Study

Participants

A total of 67 participants from the LSU community of students and staff members, DOTD staff, and the general public, comprising 18 females and 49 males with an average age of 26.8 years (Standard deviation of 8.6 years), participated in the experiment. Overall, 78 were recruited but 10 were unable to participate because of simulator sickness, an experience similar to motion sickness that causes nausea, and 1 was disqualified for non-conformance. Figure 1 shows a frequency distribution of the ages of the 67 participants that were unaffected by simulator sickness and were able to complete the experiment.

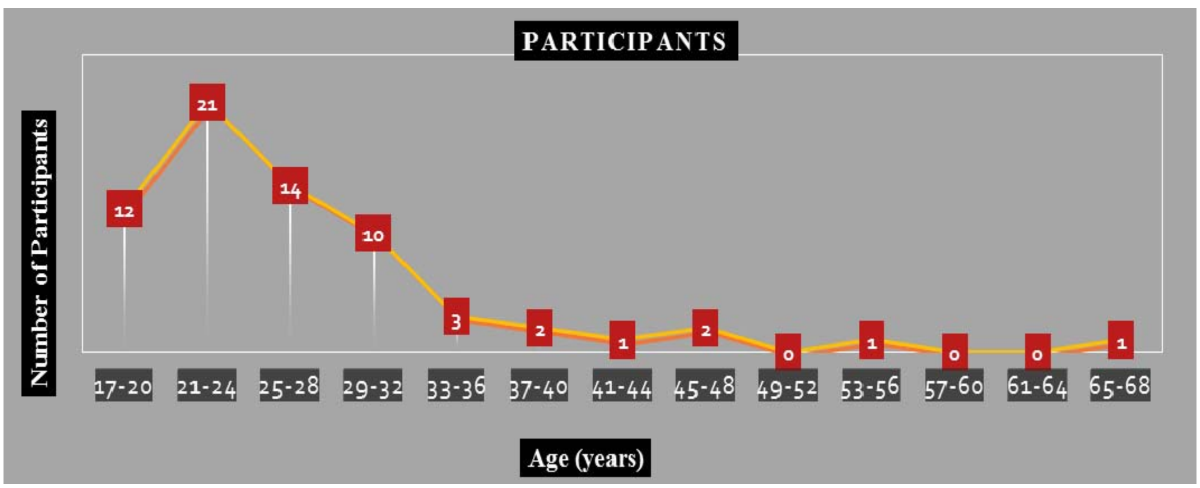


Figure 1
Distribution of age of participants

All participants were in good general health with normal or corrected visual acuity, were active drivers with a valid driver's license, and had experience using cell phone while driving. They were recruited using flyers on university bulletin boards and in accordance with the Institutional Review Board's (IRB) standards, the university's authority that regulates all research work undertaken in the university. A copy of the IRB approved documentation authorizing the undertaking of this study has been included in Appendix A.

Equipment

Participants were tested in the LSU driving simulator, a full-sized passenger car (Ford Fusion but with no wheels) combined with a series of cameras, projectors and screens to provide a high fidelity virtual environment. Some of the features of the driving simulator include the Internet Scene Assembler (ISA) and SimVista, used for modification of the virtual environment; SimCreator, used for the modification of the dynamics of the vehicle; and SimObserver, integrated with the virtual environment and used for data and video synchronization, video capture and after-action review. Figure 2 shows pictures of one side of the LSU driving simulator and some of its series of computer screens.

(a) Desktop computers (b) Ford Fusion simulator cab

Figure 2
The LSU driving simulator

Choice of Secondary Tasks

Following on from the pilot project, text messaging, handheld cell phone conversation, and front-seat passenger conversation were the three tasks chosen for the main study along with a control drive where no task was performed.

Text messaging was a key task chosen primarily because of the national media attention it has attracted as a cause of distracted driving. Texting increases the reaction time of the driver *(*Anderson et al., 2011*)* and has a higher distraction potential (Ranney et al., 2011). Other studies (Young et al., 2006; Owens et al., 2011) found that sending a text message was more distracting than receiving one with the possible explanation of longer glances away from the roadway while sending texts. Another study (Alosco et al., 2012) found there were no significant differences in the distractions caused when texting and using two different interfaces; i.e., hard button and touch pad. For this reason, it was not considered important whether the phone used for the experiment had a touch pad or hard button interface. Participants were asked to read and respond to text messages from their own personal phone.

For handheld cell phone conversation, several of the studies in Table 2 reported its increased crash potential when combined with the primary task of driving. Some other researchers have attempted to study the effect of easy and difficult phone conversation along with short and long duration call on the driving performance. These studies have found the intensity of the conversation to have no significant impact on the driving performance, but found cell phone conversation to be detrimental to driving performance (Strayer et al., 2006; Rosenbloom, 2006). Notwithstanding these findings, several others have found hands-free cell phone conversation to have no significant effect on driver performance during driving (Briem and Hedman, 1995; Törnros and Bolling, 2005; Parkes and Hooijmeijer, 2001). Yet still, a recent study by Fitch et al. (2013) concluded that neither handheld nor hands-free conversation increased the risk of crash. These inconsistencies, and the fact that Louisiana is one of the few states that still allows handheld phone conversations while driving, led to this task being chosen to be investigated for this study. Participants were asked to dial from their own personal cell phones for this task.

For front-seat passenger conversation, this task was chosen as a baseline task to compare to the text messaging and handheld cell phone conversation task. Results of two studies (Drews et al., 2004; Amado et al., 2005) showed that front-seat passenger conversation did not have any significant distracting effect, and attributed this to perhaps the lesser visual attention it required on drivers.

Experimental Design

Several experimental designs were developed for this study according to the factor being investigated. The factors considered were, for each secondary task, to test for overall distraction resulting from that specific secondary task, and also to check for effect of age, effect of driving environment, effect of weather conditions, effect of gender, and effect of the time of day. The experimental design for each factor is discussed below. Each participant was to undertake a treatment drive (comprising random events of front-seat passenger conversation, handheld phone conversation, and texting) as well as control drive of the same scenario where participants were not required to perform any task. The control drive spanned the length of the treatment drive to enable each section to be directly compared.

Overall Distraction Effect. The experiment was designed as a 1 x 4 repeated measure design with the participant as a between-subject factor, and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events: control, front-seat passenger conversation, phone conversation, and texting; data was collected for each event. The overall distraction effect considers the combined effects of age, driving environment, weather condition, gender, and time of day.

Age Effect. The experiment was designed as a 2 x 4 repeated measure design with the age of participants as a between-subject factor (two levels comprising those under 25 and those who were 25 years and above), and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events, comprising 33 participants under the age of 25 years and 34 participants at the age of 25 years and above. The age threshold of 25 years was chosen because that is the lower limit that has been defined for older drivers in the NHTSA (National Highway Traffic Safety Administration) Guidelines for Distracted Driving Studies, 2012.

Gender Effect. The experiment was designed as a 2 x 4 repeated measure design with gender as a between-subject factor (two levels comprising male and female), and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events comprising 49 males and 18 females.

Driving Environment Effect. The experiment was designed as a 2 x 4 repeated measure design with driving environment as a between-subject factor (two levels comprising urban and freeway driving environment), and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events. However, 34 experimented in urban driving conditions while 33 did in freeway driving conditions.

Time of Day Effect. The experiment was designed as a 4 x 4 repeated measure design with the driving environment and time of day as a between-subject factor (four levels comprising urban-day, urban-night, freeway-day and freeway-night), and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events. However, 17 each experimented under urban-day, urban-night, and freeway-night conditions while 16 experimented under freeway-day time conditions.

Weather Condition Effect. The experiment was designed as a 8 x 4 repeated measure design with driving environment and weather condition as a between-subject factor (eight levels comprising normal, snow, rain, and fog each under urban and freeway conditions), and event as a within-subject factor (four levels comprising control, front-seat passenger conversation, handheld phone conversation, and texting). Each of the 67 participants performed all the four events. However, 5 experimented under freeway-snow conditions; 7 under urban-snow conditions; 8 under freeway-rain conditions; 9 each under urban-fog, urban-normal and urban-rain conditions; and 10 each under freeway-fog and freeway-normal conditions.

Scenario Development

Through manipulation of appropriate software (SimVista, ISA, and SimCreator), different virtual environments were developed to represent the different driving environments, weather conditions, and time of day effects that this study investigated. The test route consisted of a divided four lane road as per NHTSA Guidelines, 2012. It had a solid double yellow line down the center, solid white lines on the outside edges, dashed white lines separating the two lanes in each direction, and on a flat grade with a speed limit of 70 mph for freeways and 35 mph for urban settings, according to Louisiana's speed limit. Both settings had cultural features commensurate with the road type, in that freeways had relatively lesser level of complexity in traffic conditions in terms of vehicular density and street furniture. Day time conditions were designed to visually represent noon visibility in real conditions while night time conditions were designed to represent 9:00 pm visibility in real conditions. All vehicles were equipped with full headlights during the night time scenarios.

Experimental Procedure

A randomization schedule was created using the SAS statistical software, and participants were allocated a specific scenario based on the randomization schedule and the order in which they were recruited. Upon arrival at the driving simulator lab, participants were briefed on the experiment and asked to review the university's IRB approved consent sheet (see Appendix A) before signing it. Participants were then asked to randomly arrange a selection of cards to determine the event order for their experiment; i.e., the order of the control, front-seat passenger conversation, handheld phone conversation, or texting drives. Each participant was allowed to familiarize with the driving simulator before tests were undertaken. Participants were asked to drive as they would normally on their way to work or college but to always stay in the right-lane and avoid changing lanes or overtaking in their respective assigned scenarios.

For the front-seat passenger conversation task, the task began when a front seat passenger begins to engage the participant in a conversation. The conversation was directed at getting the participant to orally respond to questions about his/her personal details information such as age, profession, and driving experience. Other information obtained included the participant's qualitative assessment of his/her experience during the test drive. This task ended when all questions had been answered.

For the text messaging task, participants were sent several text messages in succession to their responses. The task began as soon as participants picked up their phones to retrieve the first text message. Participants were asked to read the texts and respond accordingly. After responding to the last text message, participants had to return the phone to its original location, an empty space near the cup holder compartment in the vehicle, completing the task.

For the handheld phone conversation task, participants were asked to retrieve and dial a pre-arranged contact name from their address book. They were specifically instructed to utilize their phone's contact feature to access the stored name and call this person. Participants had to briefly explain the experiment they were involved in to the contact at the other end. The task began when participants picked up their phones and ended when the phone was returned to its original location.

For the control drive, participants were not asked to undertake any tasks. The task began when participants began to drive and ended when participants were asked to stop the vehicle. Participants were then thanked for their time and participation and escorted out of the experimentation lab. That concluded a participant's involvement in the experiment. The average time for a participant to complete the experimental procedure was 45 minutes.

Data Collection

For this study, Mean Velocity and Lane Position Variability were chosen as the performance measures that were used as surrogate measures of distraction. Velocity was measured in miles per hour and reflected the speed with which a participant drove. It was chosen to represent longitudinal control of the driving simulator. Lane Position can be defined as the position of the vehicle measured from the center of the road, in meters. A positive number indicates a vehicle on the right side of the center line while a negative number indicates a vehicle on the left. This performance measure was used to represent lateral control of the vehicle. Data were collected on these two performance measures at a frequency of 60 Hz through the SimObserver proprietary software of the driving simulator. This resulted in repeated observations taken at different time points along the route for each participant, event, and variable.

Data Description

For each experimental drive, measurements were taken at given times rather than at given locations within the course. Therefore the number of overall observations varied from one participant to the next, since the time taken to drive the course varied from one participant to the next, with some participants sending only a single text while others sent multiple texts. The number of observations per participant per event ranged from 3,000 to 44,880 observations. To summarize all such observations into one single point estimate for each participant will result in losing vital information for specific sections of the drive; likewise, to analyze all the data points for each participant will result in too much data to be processed. For this reason, the observations on each of the performance variables were broken down into one-second segments for each event. For the Lane Position variable, the standard deviation of each one-second segment data was obtained whilst for the Velocity variable, the mean of each one-second data was obtained. This summarized data resulted in a reduced number of observations for each participant with an overall range of 50 to 748 number of rows for all 67 participants. They became the focus of subsequent statistical analyses.

The one second interval was chosen because the driving simulator is able to provide sixty observations during a second interval, and this set of observations was considered sufficient to allow a time-step analysis to check for uniformity of the driving pattern. Figure 3 and Figure 4 show the distribution plots of these surrogate measures for a few participants. The x-axis denotes time in seconds; while the values on the y-axis denote the value of the standard deviation (for Lane Position) or mean (for Velocity) value corresponding to that one-second interval. The resulting distributions obtained for the control and treatment drives have each been shown and referenced.

Figure 3 shows that the Lane Position Variability distribution differs slightly according to the task that the participants were engaged in. It can be seen that the mean value increases for participants in the order of control, handheld phone conversation, front-seat passenger conversation, and texting, suggesting that distracted drivers tend to have larger lane position variability. This is because generally, when drivers take their eyes off the road, they tend to sway more in their lanes and will therefore produce greater variability in their lane positioning. It is understood that the control drive, handheld phone conversation, front-seat passenger conversation, and texting tasks requires increasing demand of the drivers to take their eyes off the road in that order, hence the pattern observed in the figure.

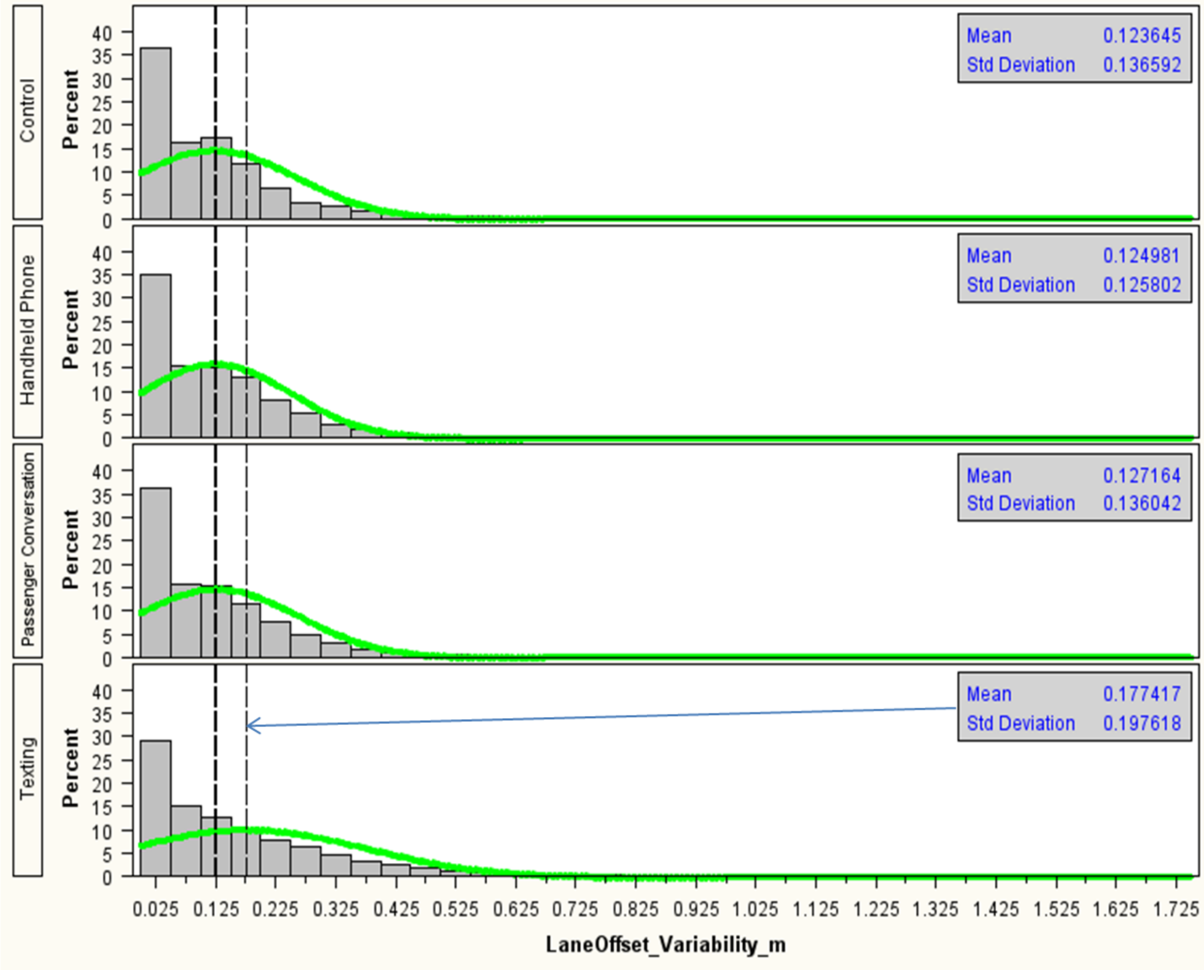


Figure 3
Distribution plot for Lane Position Variability for few participants

Figure 4 also shows that Mean Velocity distribution differs slightly according to the task that the participants were engaged in. It can be seen that the mean value increases for participants in the order of texting, passenger conversation, handheld phone conversation, and control, suggesting that distracted drivers tend to have lower speeds. This is because generally, distracted drivers will tend to have more “stop and go” driving instances than undistracted drivers, hence produce lower speeds. The bi-modal distribution of the mean velocity plot reflects the urban and freeway speed characteristics.

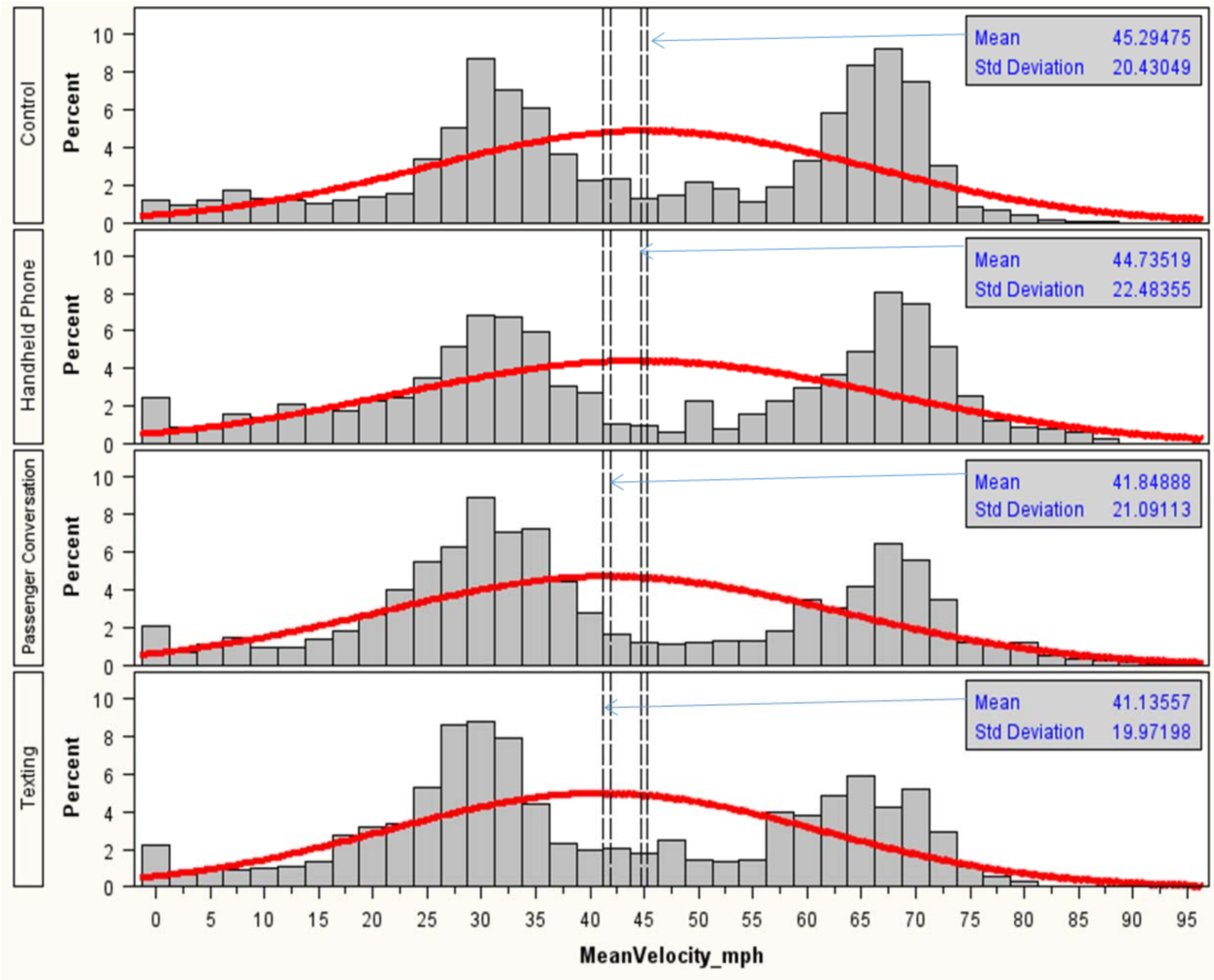


Figure 4
Distribution plot for Mean Velocity for few participants

Statistical Analysis

The Lane Position Variability and the Mean Velocity distributions of the treatment and control drives for each factor were analyzed through F-test statistics. Generally, the greater the variability, the lesser the control of the vehicle; and the lesser the variability, the greater the control of the vehicle.

ANOVA was the chosen statistical method for the data analysis through SAS Enterprise Guide. However because it was difficult to achieve normality and equality of variances for the summarized data, both being required conditions for ANOVA to produce accurate results, the Kruskal-Wallis tests, a non-parametric equivalent of ANOVA, was used. The Kruskal-Wallis tests do not require distributions to be normal and the variances to be equal and because it can be used for different sample sizes as well, was considered the best tool for this project. The hypothesis test compares the distributions of two or more samples to determine if the samples come from different populations. It uses the median as the measure of center (opposed to ANOVA’s mean as the measure of center) because it regards the data to be not necessarily symmetric. In addition, a Chi-square value, H, which has approximately the chi-square distribution with N-1 degrees of freedom (N is the number of population being compared) when the null hypothesis is true is calculated. H is a number that adds up all the discrepancies between the two distributions. Therefore a value of $H = 0$ is obtained if the two distributions are identical; and larger H values correspond to larger discrepancies between the distributions. SAS Enterprise Guide further computes a p-value, which is the probability that random sampling from groups with identical distributions would result in a test statistic value H being greater than or equal to the observed value. Lower p-values than the level of significance (5% in this case) imply that the idea that the differences between the distributions is due to random sampling can be rejected, and it can be concluded that the treatment and control drives have different distributions. Higher p-values imply the data do not give sufficient evidence to conclude that the distributions differ.

Therefore, for each of the factors investigated, the following hypotheses were tested for the lateral control of the simulator using the non-parametric ANOVA (Kruskal-Wallis) test:

$$H_O: the\ Lane\ Position\ Variability\ distributions\ of\ the\ control\\ and\ treatment\ drives\ are\ identical$$

$$H_A: the\ Lane\ Position\ Variability\ distributions\ of\ the\ control\\ and\ treatment\ drives\ are\ not\ identical$$

Similarly, for the longitudinal control of the simulator;

$$H_O: the\ Mean\ Velocity\ distributions\ of\ the\ control\\ and\ treatment\ drives\ are\ identical$$

$$H_A: the\ Mean\ Velocity\ distributions\ of\ the\ control\\ and\ treatment\ drives\ are\ not\ identical$$

A significant distracting effect is said to have occurred when the tests fail to reject the null hypothesis in favor of the alternative hypothesis in each case. In such case, the related secondary task is said to have a distracting effect on participants.

DISCUSSION OF RESULTS

Overall Distraction Effect

Results from the F-test analysis suggest that when all 67 participants are considered for longitudinal control, participants demonstrated significantly reduced control for the texting task but not for the handheld phone and passenger conversations. For lateral control, again participants demonstrated significantly reduced control for the texting task as well as the passenger conversation task but not for the handheld phone conversation task. Table 4 shows a tabulated result, with p-values and the conclusion at a 5% level of significance.

Table 4
P-values of overall distraction effect for all participants

	Lateral Control	Longitudinal Control
Handheld Phone	0.4487 Non-significant	0.5368 Non-significant
Texting	< 0.0001 Significant	< 0.0001 Significant
Passenger Conversation	< 0.0001 Significant	0.3063 Non-significant

Figure 5 shows a plot of the resulting differences from the test. The x-axis shows the treatment drive while the y-axis shows the value of the summed discrepancies between the distributions of the particular treatment drive against its corresponding control drive. Therefore, greater values suggest lesser longitudinal and lateral control.

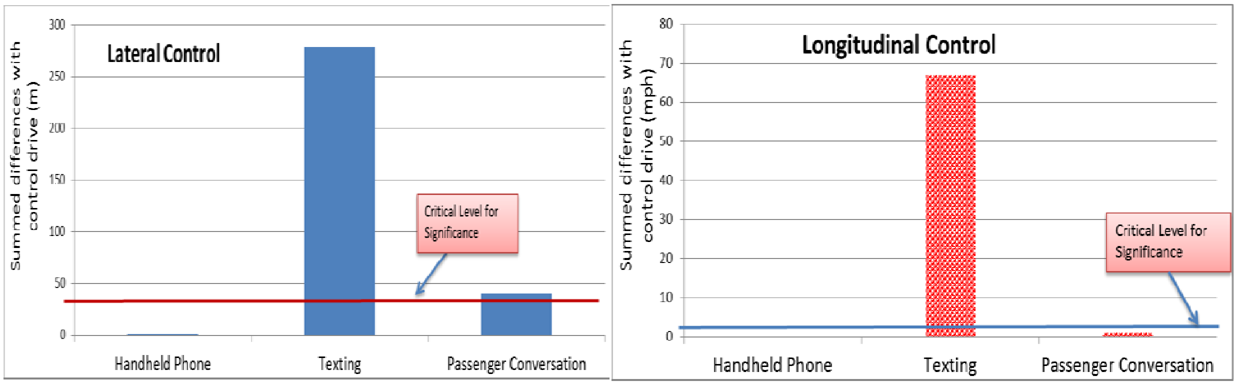


Figure 5
Overall distraction effect showing magnitude of effects

It can be seen that the summed differences between the control drive and handheld phone drive produced negligible values for both lateral and longitudinal controls in comparison to the texting task. Similarly, a negligible value was obtained for the longitudinal control component of passenger conversation in relation to texting. The figure also shows that the texting task produced the largest deviation from the control task, with the effect being more pronounced in the lateral control of the simulator than the longitudinal control. The greater lateral effect observed in the passenger conversation task when compared to the handheld phone task could be as a result of the more distracting effect of drivers probably taking their eyes off the road to look at the front seat passenger during the conversation.

Following on the above results as summarized in Table 4, a 2-sample t-test was undertaken to establish whether loss in longitudinal (lateral) control was accompanied by significant speed decreases (lane position variability increases) during the treatment drives. Again, because of the non-normality of the data, the non-parametric equivalent, Kolmogorov-Smirnov test, was undertaken. The hypotheses tested were:

$$H_O\text{: } the\ Average\ Lateral\ Position\ Variabilities\ (Mean\ Velocities) of\ the\ control\ and\ treatment\ drives\ are\ identical$$

$$H_A\text{: } the\ Average\ Lateral\ Position\ Variabilities\ (Mean\ Velocities) of\ the\ treatment\ drives\ are\ greater\ (lower) than\ than\ for\ the\ \ treatment\ drives$$

Results of the tests have been presented in Table 5.

Table 5
Results of t-test on average values of lateral position variability and mean velocity

	Average Lateral Position Variability	Average Velocity (Means)
Handheld Phone	t-statistic (1.25) p-value (0.087) Non-significant	t-statistic (4.78) p-value (<0.0001) Significant
Texting	t-statistic (7.98) p-value (<0.0001) Significant	t-statistic (5.70) p-value (<0.0001) Significant
Passenger Conversation	t-statistic (4.27) p-value (<0.0001) Significant	t-statistic (2.75) p-value (<0.0001) Significant

For each treatment drive, the topmost figure represents the Kolmogorov-Smirnov test statistic, followed by the p-value of the test, and then the conclusion at a 5% level of significance. The results for the average lateral position variability agreed with that of the hypothesis tests on the distribution, in that there was no significant increase for the handheld phone, but there were significant increases in the texting and passenger conversation tasks. However for the average velocity, there were significant decreases in speeds for all three tasks, different from the results obtained for the distribution tests. This goes to show that depending on the surrogate measures of distraction used, different conclusions may be made on the distracting effects of the secondary tasks. The results also suggest that even though participants maintained longitudinal control of the vehicle during the handheld phone and passenger conversation drives, they were probably able to do so by significantly decreasing their speeds. However for the texting drive, even though they significantly adjusted their speed, the extent of the distraction was such that participants still lost longitudinal control of the vehicle.

Furthermore, the relation between lateral control and the ability to adjust speed was explored through looking at the correlations between the Lane Position Variability and Mean Velocity observations for all 67 participants, grouped under each treatment, and presented in Table 6. It shows the results of the Spearman correlation coefficient between the two variables, along with corresponding p-values.

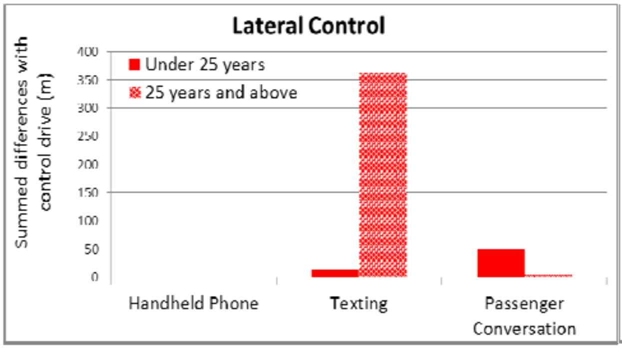
Table 6
Correlation results between Lane Position Variability and Mean Velocity

	Spearman Correlation Coefficient	P-value
Handheld Phone	0.01834	0.0607
Texting	0.01234	0.2965
Passenger Conversation	-0.02087	0.0308

The correlation statistically tests whether the relationship between the two variables is existent or not but does not establish causality. The p-values suggest that apart from the passenger conversation task, no significant relationship exists between lateral control of the vehicle and the change in speed during the respective treatment drive. The Spearman correlation coefficient is a non-parametric measure of association of the variables that scores between -1 to 1. The negative value of the coefficient associated with the passenger conversation task provides evidence of a negative relationship between Mean Velocity and Lane Position Variability during that drive. Since the passenger conversation drive resulted in significant reduced lateral control, the negative correlation implies that participants did not adjust their speed much and this resulted in a non-significant reduced longitudinal control as confirmed by Table 5. Texting and handheld phone drives show positive correlations between the Mean Velocity and Lane Position variability variables but the association is non-significant.

Age Effect

This test was undertaken to determine which of the two age groups – 33 participants under the age of 25 years versus 34 participants at 25 years and above – demonstrated more deviation from their control drives. Figure 6 shows a graphical illustration of the results.



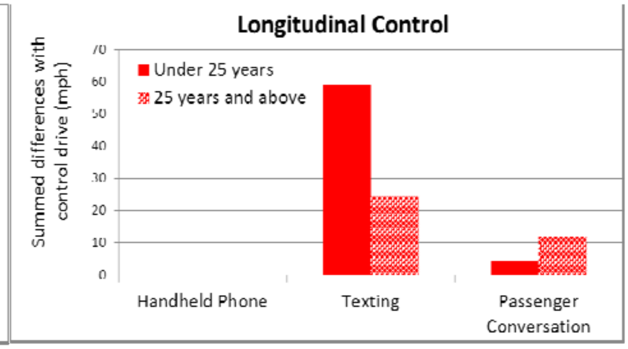


Figure 6
Age effect on lateral and longitudinal control.

The figure suggests that, generally, the younger drivers demonstrated better lateral control but worse longitudinal control than the older participants. Again, texting produced the largest differences but with older drivers performing worse in the lateral control of the vehicle than the younger drivers did in the longitudinal control of the vehicle. The passenger conversation task produced very little deviation from the control drive whilst handheld phone task produced negligible variation in each group for both lateral and longitudinal control of the vehicle.

Gender Effect

This test was undertaken to determine whether the 18 females or 49 males demonstrated more deviation from their control drives.

Figure 7 shows a graphical illustration of the results. It shows that the deviations produced by the handheld phone and passenger conversation tasks paled in comparison to the texting task, and there were no distinct differences between males and females in the longitudinal and lateral control over the vehicle during these drives.

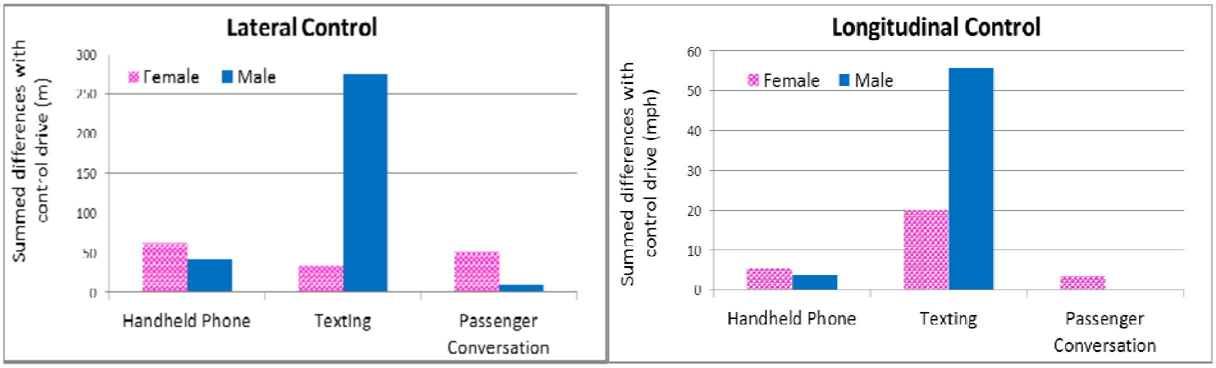


Figure 7
Gender effect on lateral and longitudinal control.

On the other hand, texting produced the largest deviations with the females demonstrating much better longitudinal and lateral control than the males.

Driving Environment

This test was undertaken to determine whether performing tasks in freeway settings provided more deviations from the control drives than when driving in urban settings. Of the participants, 34 drove in urban environments while 33 participants drove in freeway settings. The result is graphically illustrated in Figure 8.

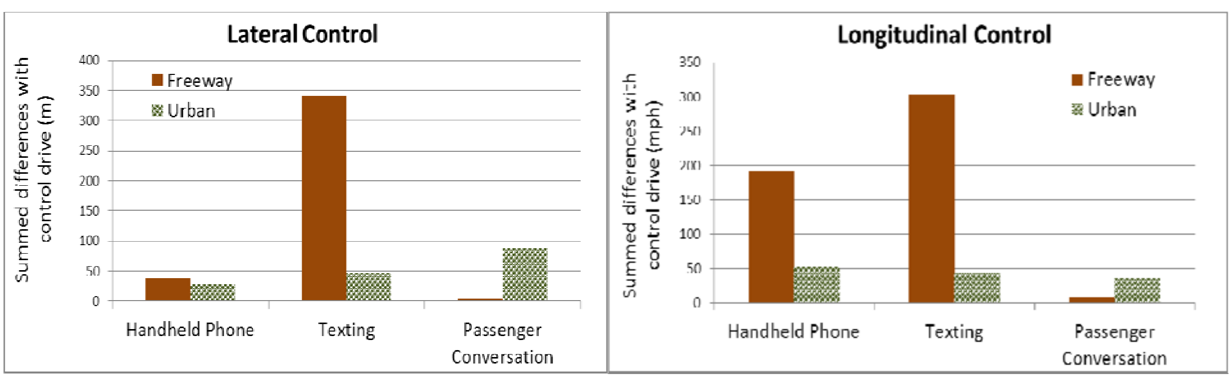


Figure 8
Driving environment effect on lateral and longitudinal control.

The figure shows that texting on freeways produces very high deviations from the control drive for both longitudinal and lateral control of the vehicle. Handheld phone conversation also produces larger deviations on freeways than on urban settings but are not as sharp as texting.

For passenger conversation, urban settings produced more deviation in both the lateral and longitudinal control of the vehicle. Figure 9 shows the speed profile of participants for the freeway and urban setting. Values on the x-axis represents specific participants and values on y-axis represent the participant's corresponding difference in mean velocities between the control drive and the treatment drive. Positive y-values therefore imply a decrease in mean speed and negative y-values imply a mean speed increase from the control to the treatment drive.

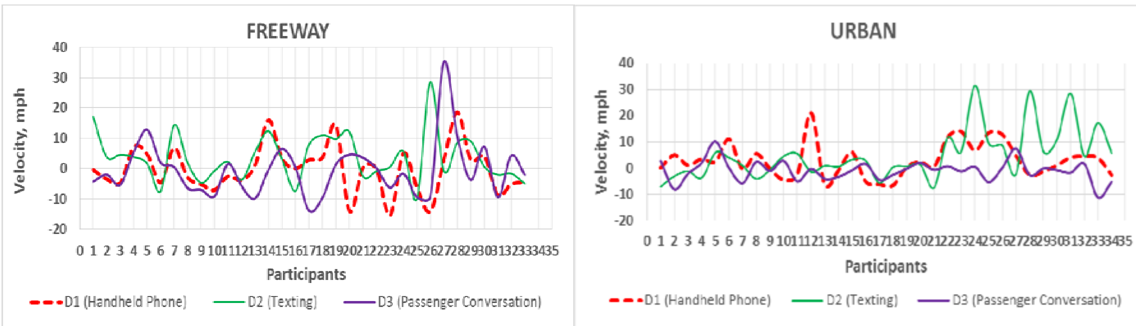


Figure 9
Speed profile of participants for driving environment

It can be observed that for freeways, all three tasks caused similar reduction of mean speeds among all participants. However for urban settings, texting caused the most reduction in mean speed, followed by phone and then passenger conversation. Individual mean speed values of participants have been included in Appendix B.

Time of Day Effect

This test was undertaken to find whether the time of day influenced the driving behavior of distracted drivers in urban and freeway settings. Seventeen drivers each experimented under urban-day, urban-night, and freeway-night conditions while 16 experimented under freeway-day time conditions. Figure 10 shows that on freeways, the loss of lateral and longitudinal control due to handheld phone task was more pronounced during day time as opposed to that due to texting being more pronounced in the night, probably due to lesser visibility in night time conditions. Daytime passenger conversation did not cause much deviation as did night time especially for the longitudinal control of the vehicle. The mean speed differences between the control and treatment drives across participants have been presented in Figure 11. This shows that for freeways, the handheld phone task resulted in more reduced mean speeds during the daytime than for the night. There were no obvious marked differences for the texting and passenger conversation tasks. Individual mean speeds for participants have been included in Appendix B.

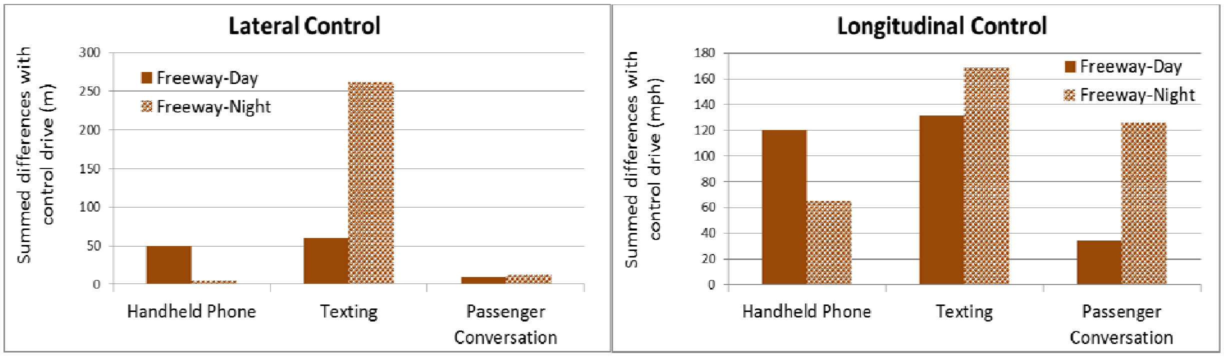


Figure 10
Time of day effect on freeway settings

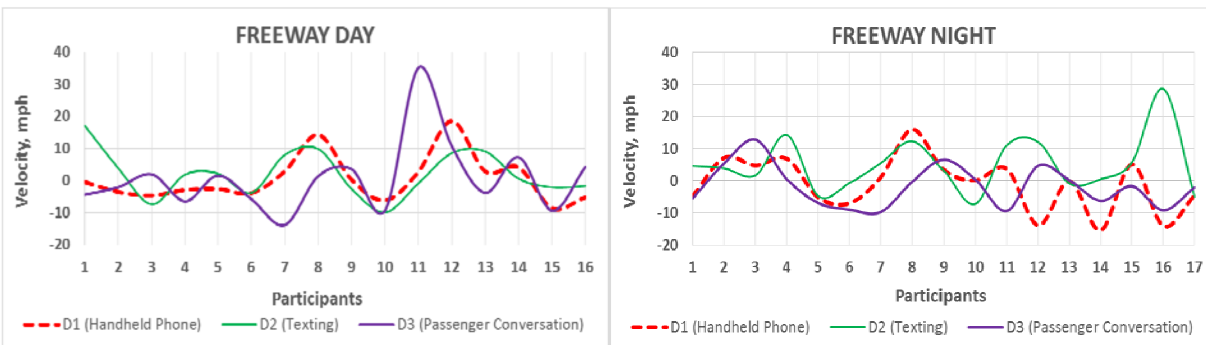


Figure 11
Speed profile of participants for freeway time of day

Figure 12 shows that both the handheld phone and passenger conversation tasks caused increased loss of lateral and longitudinal control of the vehicle during night times on urban roads. Surprisingly, texting was worse during the day than the night in these settings.

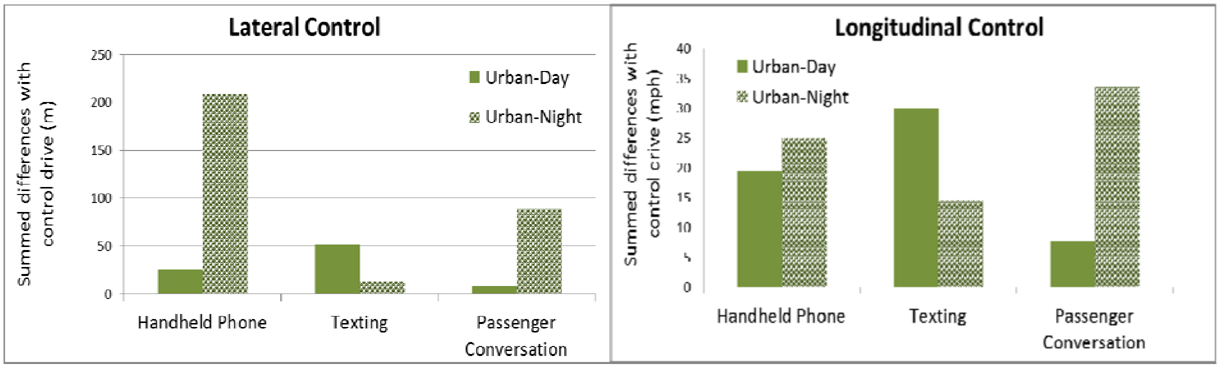


Figure 12
Time of day effect on urban settings

An observation of the speed profile for all participants, as shown in Figure 13, shows that identical reduction in mean speeds were observed for all participants during the daytime and night time conditions in urban settings. However, there were few participants that demonstrated remarked speed reduction during the day time than for the night time during the texting task. Individual mean speeds for participants have been included in Appendix B.

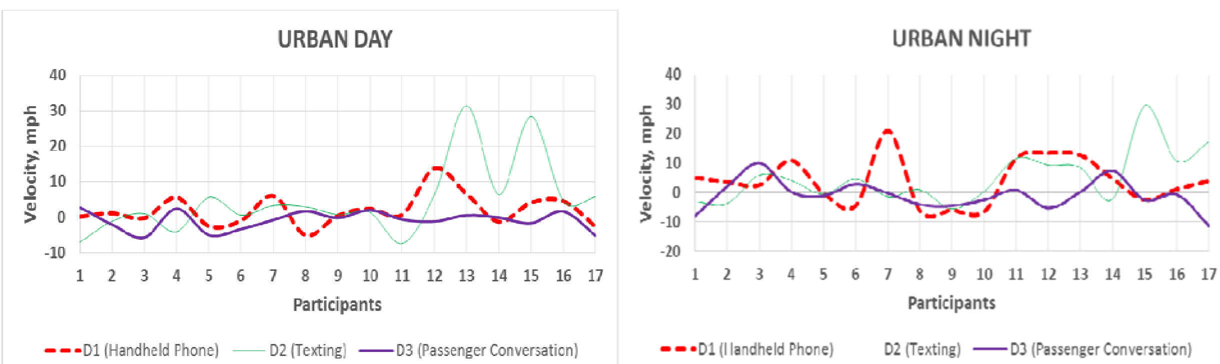


Figure 13
Speed profile of participants for urban time of day

Weather Condition Effect

This test investigated the driving patterns of distracted drivers under different weather conditions to see if there was a weather effect. Again, the effect was tested separately for freeways and urban settings. For the freeway settings, 5 experimented under snowy conditions, 8 under rainy conditions, and 10 each under foggy and normal conditions. For the urban settings, 7 drove under snowy conditions and 9 each under the other conditions. Figure 14 to show the results obtained.

Figure 14 shows a wide range of weather condition effects in freeway settings with no obvious trend. Drivers engaged in passenger conversation were not affected much by the weather conditions in the lateral and longitudinal control of the vehicle. Participants undertaking the handheld task did not show any obvious effects from the weather conditions on their longitudinal control of the vehicle but demonstrated reduced longitudinal control in foggy and snowy conditions. Texting seemed to produce some marked deviations in both lateral and longitudinal control of the vehicle but no single condition was prevalent.

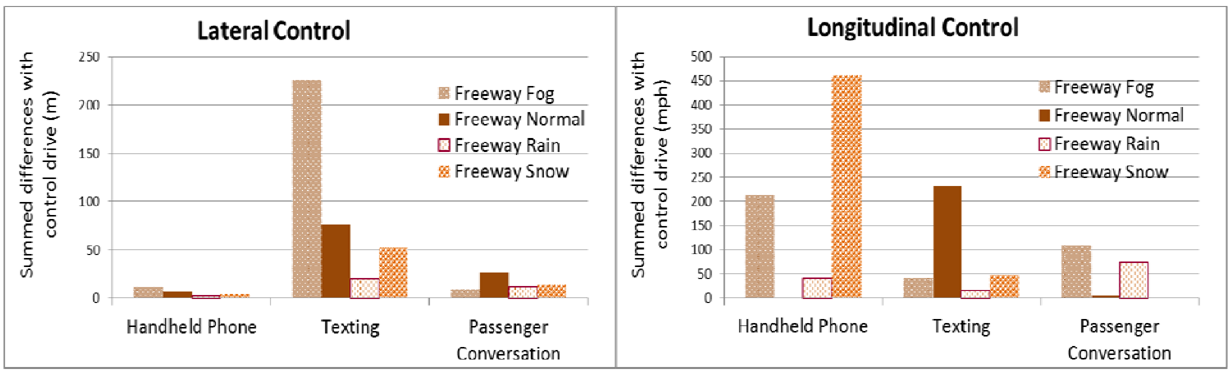


Figure 14
Weather condition effect on freeway settings

Overall, participants in the rainy and normal conditions seemed to perform better than in any of the remaining weather conditions but no conclusion can be determined for those that performed worse.

Figure 15 presents a mean speed profile for the respective participants that were tested under each condition. Overall, it shows that the texting event resulted in reduced mean speed values more than any of the other tasks for all weather conditions on the freeway. Individual mean speeds for participants have been included in Appendix B.

Figure 16 also shows a wide range of weather condition effects on urban settings but it can be seen that for all tasks, drivers performed relatively better during normal weather conditions. Passenger conversation and handheld phone conversation produced more lateral deviations during rainy conditions. On the other hand, texting and handheld phone conversation produced more longitudinal deviations during snowy conditions.

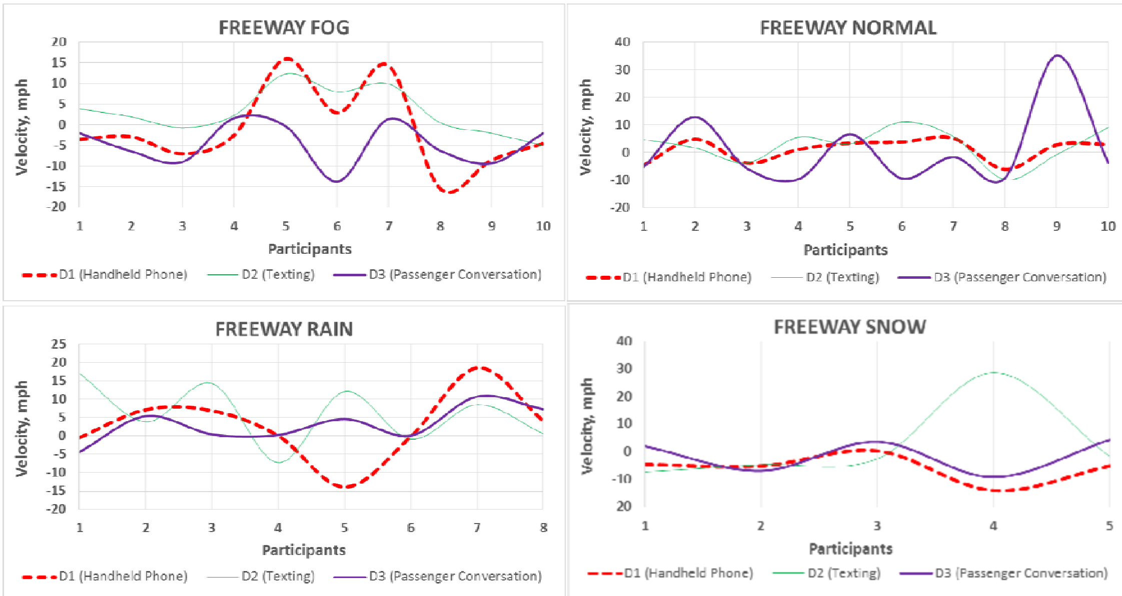


Figure 15
Speed profile of participants for freeway weather conditions

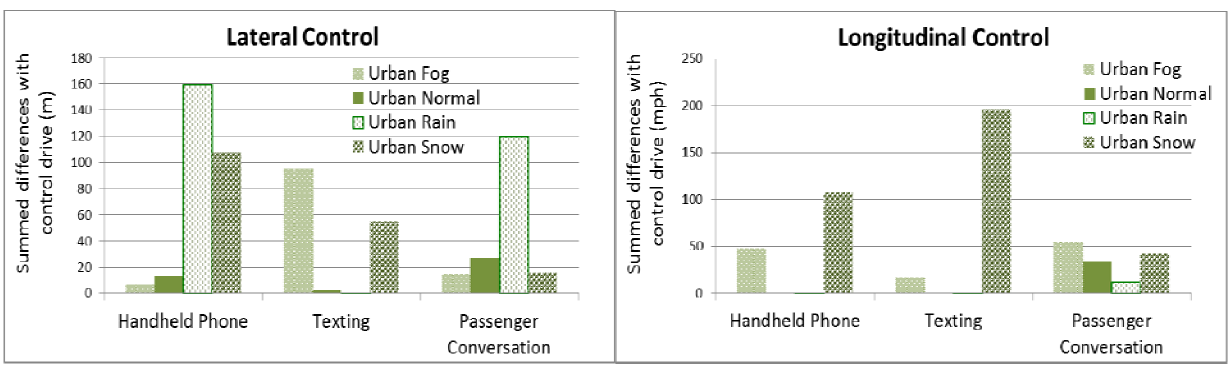


Figure 16
Weather condition effect on urban settings

Figure 17 presents a mean speed profile for the respective participants that were tested under each condition. Overall, it shows that the texting and handheld events resulted in reduced mean speed values more than the passenger conversation task for all weather conditions on the urban roads. Individual mean speeds for participants have been included in Appendix B.

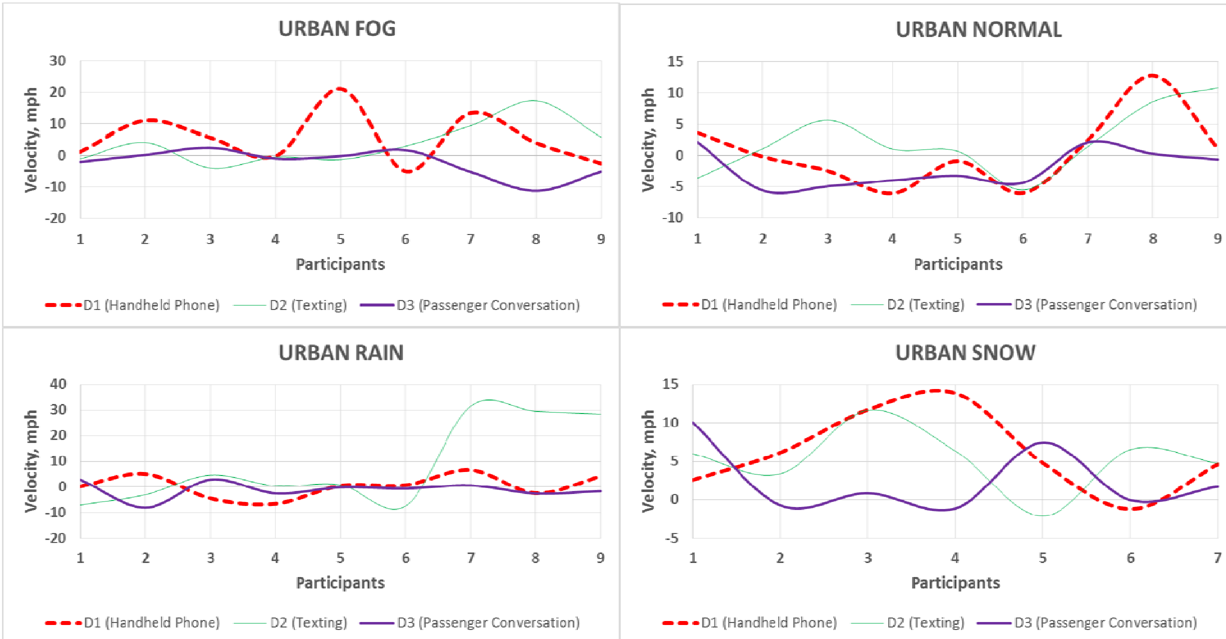


Figure 17
Speed profile of participants for urban weather conditions

Summary of Research Findings

This section provides a summary of the research findings in a form of a table, and is shown in Table 7. “S” stands for a significant effect and “NS” stands for a non-significant effect at the 5% level of significance. All asterisks (*) indicate that the particular condition had the most deviation out of the remaining conditions for that factor. Those have been selected purely on the magnitude of their deviations from their corresponding control drives, and not on a statistically significance basis. Actual Chi-square values corresponding to the summed differences between the distributions of the treatment drives and corresponding control drives (summed deviations) have been presented in Appendix C.

Table 7
Summary of research findings

			REDUCED LATERAL CONTROL			REDUCED LONGITUDINAL CONTROL		
			Handheld Phone Conversation	Texting	Front Seat Passenger Conversation	Handheld Phone Conversation	Texting	Front Seat Passenger Conversation
		Overall Effect	NS	S	S	NS	S	NS
Age		< 25 years			*	*	*	
		≥ 25 years	*	*				*
Gender		Female	*		*	*		*
		Male		*			*	
Environme		Freeway	*	*		*	*	
		Urban			*			*
Time of Day	Freeway	Day	*			*		
		Night		*	*		*	*
	Urban	Day		*			*	
		Night	*		*	*		*
Weather	Freeway	Fog	*	*				*
		Normal			*		*	
		Rain						
		Snow				*		
	Urban	Fog		*				*
		Normal						
		Rain	*		*			
		Snow				*	*	

Note: NS = non-significant distracting effect; S = significant distracting effect; * = no statistical tests undertaken but magnitude shows condition has the most distracting effect

CONCLUSIONS AND RECOMMENDATIONS

Distracted driving continues to gain media attention and research interest because of its elevated crash risks and the difficulty in getting drivers to adjust their lifestyles to overcome this epidemic. Using a cell-phone while driving is one of the causes of distracted driving in the United States and many studies have been conducted to analyze its effect on driver performance. This study analyzed the effect of being engaged in a handheld cell phone conversation, cell phone texting, and front-seat passenger conversation while driving under different weather and environmental conditions. Two variables, lane position variability and mean velocity, were used as performance measures to respectively represent lateral and longitudinal control of the driving simulator. The results of the study, which agree with findings from some previous studies, suggest that, overall, being engaged in a hand-held cell phone conversation while driving did not provide significant lateral or longitudinal deviation from driving without distraction, while participants significantly adjusted their speeds to compensate for distraction. However, some other studies, also referenced in this report, have found the use of both handheld and hands-free cell phone conversation to be distracting. The inconsistencies in conclusions from research on the distracting effect of cell-phone conversation could be attributed to the nature of the conversation itself and its impact on the driver's mood: conversations that involve significant cognitive effort such as retrieval of information from memory, and other emotional and distressing types will have higher impact on a driver's concentration levels more than would a normal conversation. In this study, however, participants were engaged in normal conversation that did not cause any distress and, consequently, no significant impact was detected.

On the contrary, the results of this study suggest that texting while driving resulted in significant lateral and longitudinal deviations from what would be observed when not distracted. While participants still significantly adjusted their speeds during the texting event, the extent of the distraction was such that the speed reduction could not compensate for it. Again, this result agreed with other past studies referenced in this report. All studies reviewed in the literature found texting to produce a distracting effect while driving. The consensus on the distracting nature of texting may also explain why as many as 41 U.S. states (including Louisiana) have banned drivers from texting while only 12 U.S. states (excluding Louisiana) prohibit all drivers from using handheld cell phones. The significant distracting effect of texting could be attributed to the fact that texting involves more visual demand on the participant than cell phone conversation. This may also explain why front-seat passenger conversation produced more significant lateral deviations but cell phone conversation did not. Nevertheless, there were no significant longitudinal deviations from the front-seat passenger conversation. Findings from this study lend credence to the many bodies that support the ban on texting while driving.

Additionally, this study analyzed the distracting effect under several environmental and driving conditions. Gender and age effect on the level of distraction was also investigated. Generally, it was observed that younger drivers (aged under 25 years) demonstrated better lateral control but worse longitudinal control than older participants (aged 25 years and above). Females, in general, also demonstrated better lateral and longitudinal control of the vehicle than males. The environment of the driving also seemed to have an effect on drivers engaged in distracting tasks. The results showed that drivers on freeways produced worse longitudinal and lateral control of the simulator than drivers in urban surroundings. This could be a result of the generally lower speeds and "stop and go" driving conditions of urban surroundings as a result of the interrupted traffic flow caused by traffic lights and probably higher traffic densities. The time of day effect (day or night) and weather conditions (snow, normal, fog, and rain) were also investigated under urban and freeway settings. For freeways, the effect of night time driving on the texting task produced significant lateral deviations than texting during the day time. This could be explained by the reduced visibility at night and the fact that texting is usually more difficult on freeways. For the remaining tasks, the loss of control was more noticeable during the day. However, the weather conditions that produced distinct effects on freeway settings were fog (during texting) and snow (during handheld cell phone conversation). For urban settings, surprisingly, texting during the day was worse than at night, while engaging in handheld phone and passenger conversation during the night was worse than during the day. The weather conditions that produced noticeable effects on urban settings were rain (during handheld phone and passenger conversation) and snow (during texting).

It is recommended that future research make use of the vast experimental data collected for this project and the recent availability of naturalistic driving data to further investigate the effect of task duration (number of text messages exchanged) on the level of distraction experienced by drivers. Also, driving patterns of each individual can be analyzed to determine whether the moment of distraction can be pinpointed and then compared to the video data. More importantly, a distraction index can be developed from several surrogate measures of distraction that will accurately predict the crash risk of several secondary tasks. Being able to accurately determine the moment distracted driving patterns begin could have significant impact on the development of preventive measures and devices that can provide useful post-crash data.

ACRONYMS, ABBREVIATIONS, & SYMBOLS

ANOVA	Analysis of Variance
CAN	Controller Area Network
DOT	Department of Transport
DOTD	Louisiana Department of Transportation and Development
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
IRB	Institutional Review Board
ISA	Internet Scene Assembler
IVS	In-vehicle Systems
LSU	Louisiana State University
LTRC	Louisiana Transportation Research Center
NHTSA	National Highway Traffic Safety Administration
PRC	Project Review Committee
U.S.	United States (of America)
UTC	University Transportation Center

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APPENDIX A (IRB APPROVED DOCUMENTATION)

This appendix shows the approved documentation from the University's Institutional Review Board (IRB). The role of the IRB is to facilitate research, protect research participants, and comply with all research regulations.

ACTION ON PROTOCOL APPROVAL REQUEST

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

TO: Sherif Ishak
Civil Engineering

FROM: Robert C. Mathews
Chair, Institutional Review Board

DATE: February 22, 2013
RE: **IRB#** 3371

TITLE: Distracted Driving and Associated Crash Risks

New Protocol/Modification/Continuation: New Protocol

Review type: Full ___ Expedited _X_ **Review date:** 2/25/2013

Risk Factor: Minimal __X__ Uncertain ______ Greater Than Minimal______

Approved____X____ **Disapproved**__________

Approval Date: 2/25/2013 **Approval Expiration Date:** 2/24/2014

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 100

Protocol Matches Scope of Work in Grant proposal: (if applicable)______

By: Robert C. Mathews, Chairman Robt C Mathews

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

Application for Approval of Projects Which Use Human Subjects

This application is used for projects/studies that cannot be reviewed through the exemption process.

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

– Applicant, Please fill out the application in its entirety and include two copies of the competed application as well as parts A-E, listed below. Once the application is completed, please submit to the IRB Office for review and please allow ample time for the application to be reviewed. Expedited reviews usually takes 2 weeks. Carefully completed applications should be submitted 3 weeks before a meeting to ensure a prompt decision.

– A Complete Application Includes All of the Following:

(A) Two copies of this completed form and two copies of part B thru F.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
(F) IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator*: Sherif Ishak **Rank** Associate Professor
*PI **must be** an LSU Faculty Member

Dept: Civil Engineering **Ph:** 578-4846 **E-mail:** sishak@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each
Julius Codjoe, Graduate Student, jcodjo1@lsu.edu

IRB# 3371 LSU Proposal #_____

- Full
- Expedited
- Human Subjects Training
- Complete Application

3) Project Title: Distracted Driving and Associated Crash Risks

4) Proposal Start Date: 07/01/2012 **5) Proposed Duration Months:** 18

6) Number of Subjects Requested: 100 **7) LSU Proposal #:** 39263

8) Funding Sought From: UTC and LTRC

Study Approved By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Approval Expires: 2/24/2014

ASSURANCE OF PRINCIPAL INVESTIGATOR named above
I accept personal responsibility for the conduct of this study (including ensuring compliance of co-investigators/co-workers) in accordance with the documents submitted herewith and the following guidelines for human subject protection: The Belmont Report, LSU's Assurance (FWA00003892) with OHRP and 45 CFR 46 (available from http://www.lsu.edu/irb). I also understand that copies of all consent forms **must be maintained at LSU for three years after the completion of the project.** If I leave LSU before that time, the consent forms should be preserved in the Departmental Office.

Signature of PI Sherif Ishak Date 02/15/2013

ASSURANCE OF STUDENT/PROJECT COORDINATOR named above. If multiple Co-Investigators, please create a "signature page" for all Co-Investigators to sign. Attach the "signature page" to the application.

I agree to adhere to the terms of this document and am familiar with the documents referenced above.

Signature of Co-PI (s) Julius Codjoe Date 02/15/2013

Study Approved By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Approval Expires: 2/24/2014

CONSENT FORM

1. Study Title: Distracted Driving and Associated Crash Risks

2. Performance Site: Louisiana State University and Agricultural and Mechanical College, Patrick F. Taylor Hall, Room 2225.

3. Investigators: The following investigators are available for questions about this study, M-F, 9:00am – 5:00pm: Dr. Sherif Ishak, 578-4846, sishak@lsu.edu; Julius Codjoe, jcodjo1@lsu.edu.

4. Purpose of the Study: This study investigates the use of the driving simulator on the LSU campus to measure risks associated with various distractions faced by the driving population.

5. Subject Inclusion: Subjects between the ages of 18 and 65 with normal or corrected to normal vision and possessing a driver's license.

6. Number of Subjects: 100

7. Study Procedures: Subjects will be asked to drive the LSU driving simulator as they would normally drive a real vehicle to work and will be exposed to differing driver distractions to determine the effect on the driving task. The study will take approximately 45 to 60 minutes to complete.

8. Benefits: This will assist highway safety professionals in developing behavioral strategies to mitigate crashes due to distracted driving.

9. Risks: Driving simulators may cause conditions known as simulator sickness. These conditions are similar to motion sickness, or those sensations one feels when flying, the symptoms of which include eyestrain, headache, postural instability, sweating, disorientation, vertigo, pallor, and nausea. If you have a predisposition towards motion sickness of any kind, please inform any of the investigators immediately. If you feel any discomfort, please press the emergency safety knob in the simulator at any time. This will bring the simulation to a stop. As a subject, using the immediate termination action during a session or otherwise will NOT penalize you for any loss or benefit you would otherwise have received. You are therefore encouraged to use this device as soon as you feel the slightest discomfort.

10. Right to Refuse: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

11. Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless disclosure is required by law.

12. Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I may contact Dr. Robert Mathews, Chair of the Institutional Review Board, 203 B-1 David Boyd Hall, Baton Rouge, LA 70803, or by phone on (225) 578-8692. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Signature of Subject ______________________________

Printed Name ______________________________

Date ______________________________

Project Report and Continuation Application

(Complete and return to IRB, 130 David Boyd Hall.
Direct questions to IRB Chairman Robert Mathews 578-8692.)

LSU
Institutional Review Board
Dr. Robert Mathews, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

IRB#: 3371 **Your Current Approval Expires On:** 2/24/2014

Review type: Expedited **Risk Factor:** Minimal **Date Sent:** 12/2/2013

PI: Sherif Ishak **Dept:** Civil Engineering **Phone:** Aug-46

Student/Co-Investigator: Julius Codjoe

Project Title: Distracted Driving and Associated Crash Risks

Number of Subjects Authorized: 100

Please read the entire application. Missing information will delay approval!

I. PROJECT FUNDED BY: UTC, LTRC **LSU proposal #:** 39263

II. PROJECT STATUS: Check the appropriate blank(s); and complete the following:

- ___ 1. **Active, subject enrollment continuing;** # subjects enrolled: ___
- ___ 2. **Active, subject enrollment complete;** # subjects enrolled: ___
- ___ 3. **Active, subject enrollment complete;** work with subjects continues.
- ✓ 4. **Active, work with subjects complete;** data analysis in progress.
- ___ 5. **Project start postponed**
- ___ 6. **Project complete;** end date __/__/__
- ___ 7. **Project cancelled:** no human subjects used.

III. PROTOCOL: (Check one).

- ✓ Protocol continues as previously approved
- ___ Changes are requested*
  - *List (on separate sheet) any changes to approved protocol.*

IV. UNEXPECTED PROBLEMS: (did anything occur that increased risks to participants):

- State number of events since study inception: 0 since last report: ___
- If such events occurred, describe them and how they affect risks in your study, in an attached report.
- Have there been any previously unreported events? Y/N N ?
  (If YES, attach report describing event and any corrective action).

V. CONSENT FORM AND RISK/BENEFIT RATIO:

Does new knowledge or adverse events change the risk/benefit ratio? Y/N N.
Is a corresponding change in the consent form needed? Y/N N

VI. ATTACH A BRIEF, FACTUAL SUMMARY of project progress/results to show continued participation of subjects is justified; or to provide a final report on project findings. N/A. Data Analysis in Progress.

VII. ATTACH CURRENT CONSENT FORM (only if subject enrollment is continuing); and check the appropriate blank:

- ✓ 1. Form is unchanged since last approved
- ___ 2. Approval of revision requested herewith: (identify changes)

Signature of Principal Investigator: [signature] **Date:** 12/5/13

IRB Action: ✓ Continuation approved; Approval Expires: 2/5/14	
___ Disapproved	
___ File closed	
Signed [signature]	Date 12/6/13

Form date: April 16, 2008

B (INDIVIDUAL MEAN SPEED PROFILES)

This appendix shows the individual mean speed profiles for all participants grouped by task.

Appendix B1 shows the mean speed profiles for participants who experimented under the Driving Environment factor.

Appendix B2 shows the mean speed profiles for participants who experimented under the Time of Day factor.

Appendix B3 shows the mean speed profiles for participants who experimented under the Weather Condition factor.

Appendix B1 – Driving Environment Factor

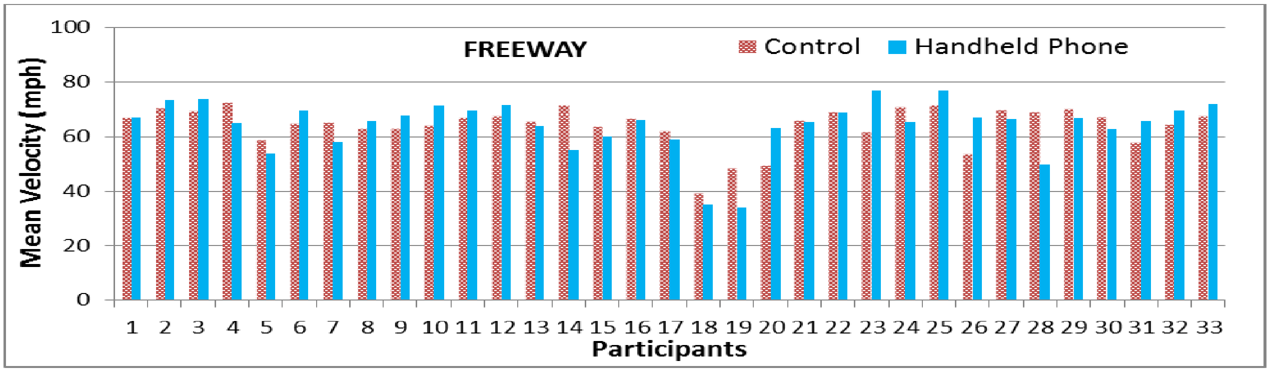

Figure B1-1

Speed profile for Control vs. Handheld Phone for freeway environment

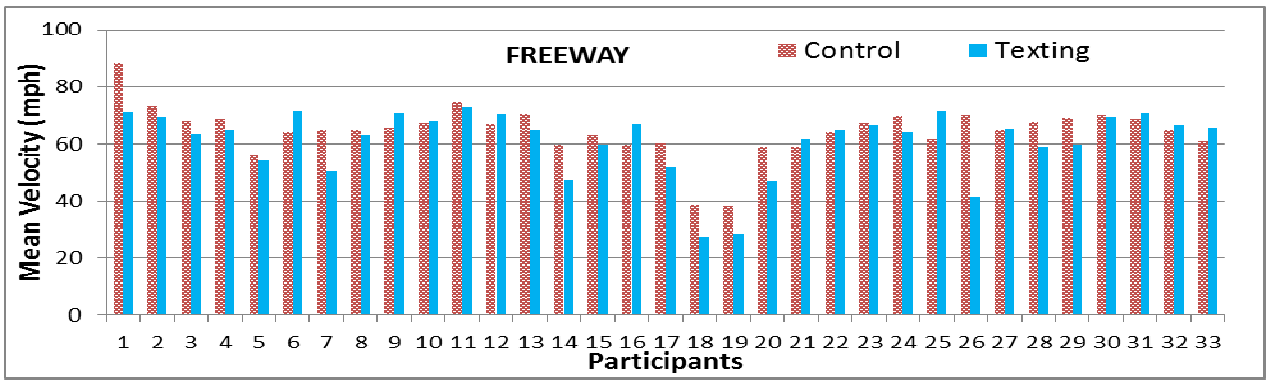

Figure B1-2

Speed profile for Control vs. Texting for freeway environment

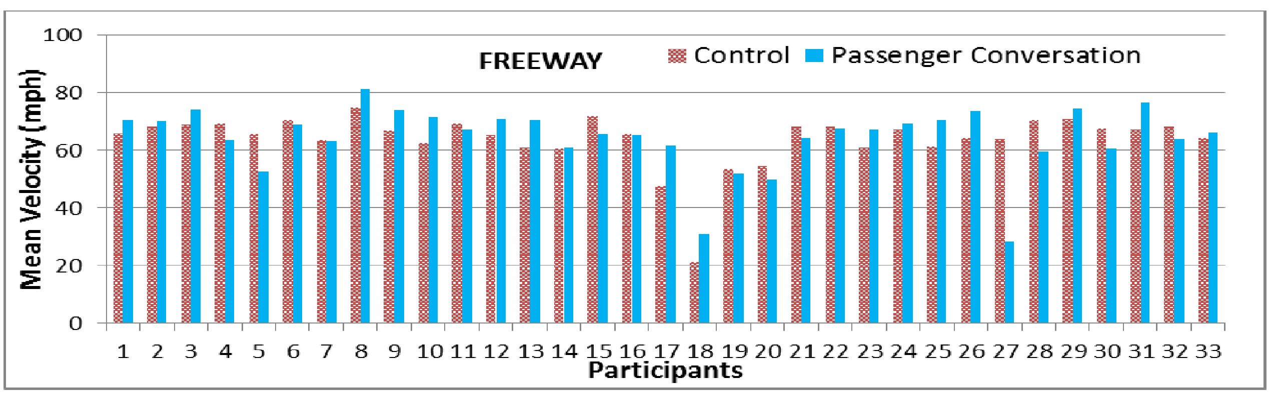

Figure B1-3

Speed profile for Control vs. Passenger Conversation for freeway environment

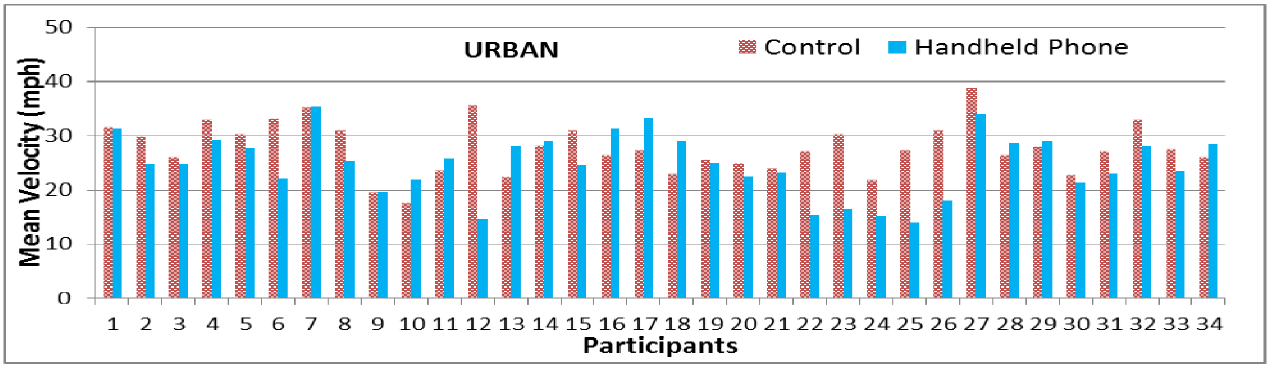

Figure B1-4

Speed profile for Control vs. Handheld Phone for urban environment

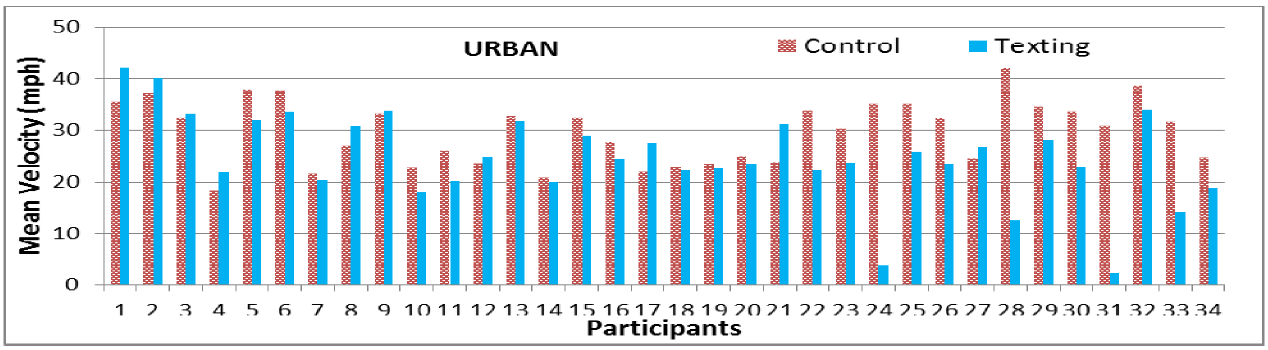

Figure B1-5

Speed profile for Control vs. Texting for urban environment

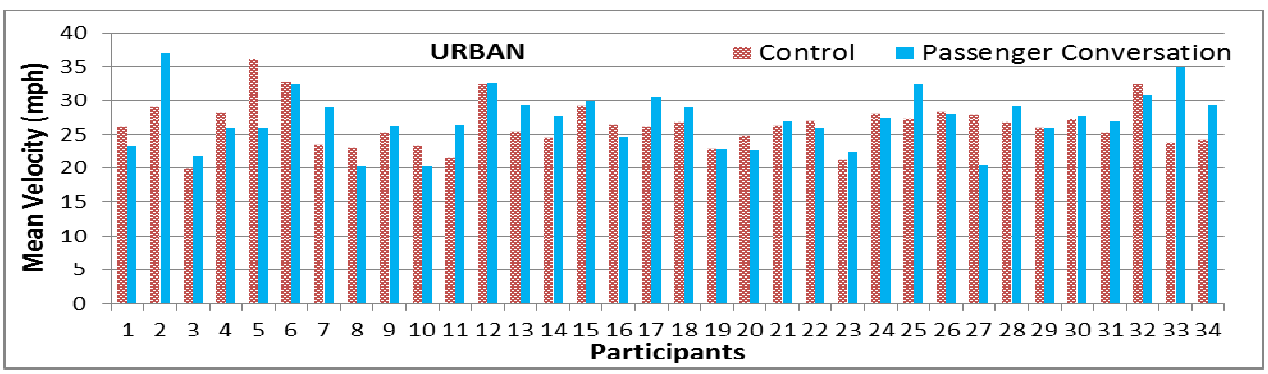

Figure B1-6

Speed profile for Control vs. Passenger Conversation for urban environment

Appendix B2 – Time of Day Factor

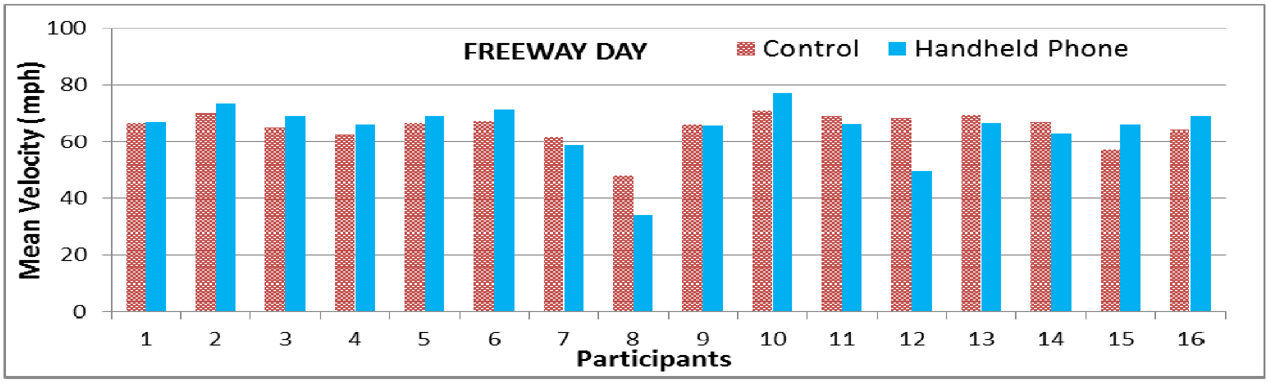

Figure B2-1

Speed profile for Control vs. Handheld Phone for freeway-day environment

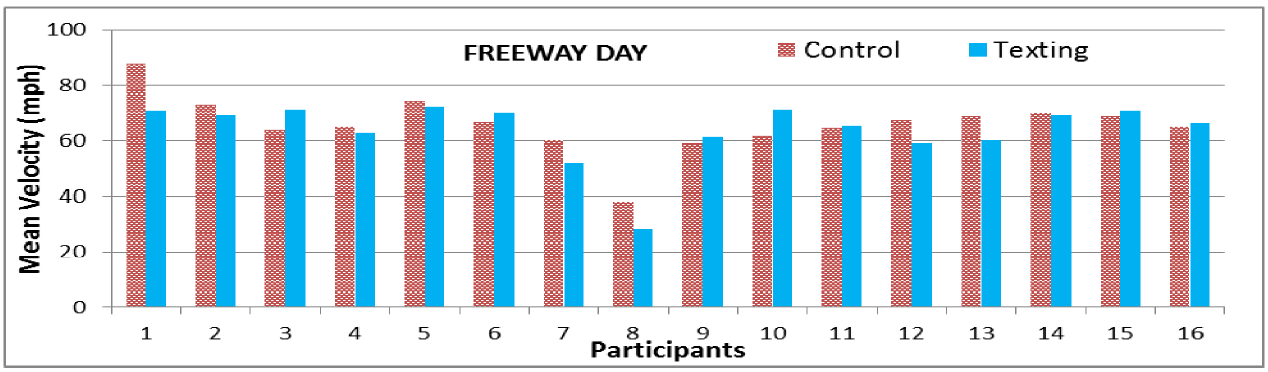

Figure B2-2

Speed profile for Control vs. Texting for freeway-day environment

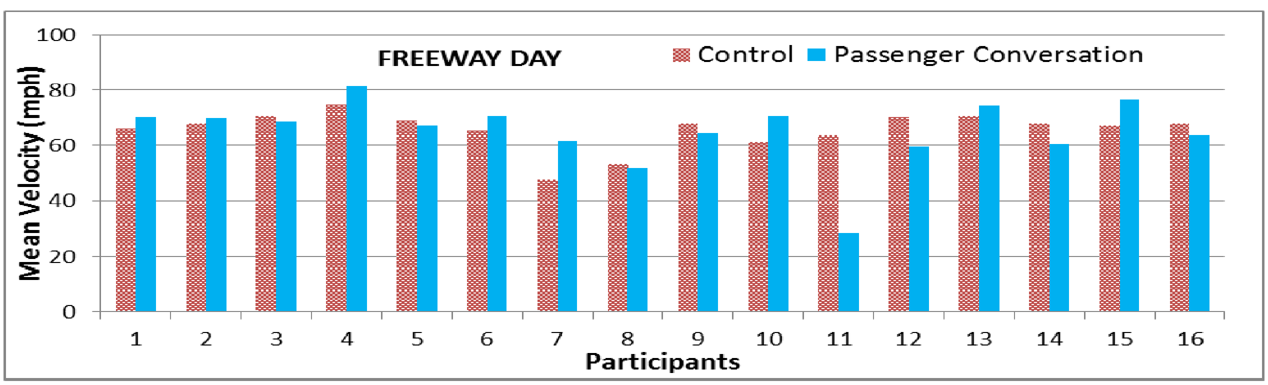

Figure B2-3

Speed profile for Control vs. Passenger Conversation for freeway-day environment

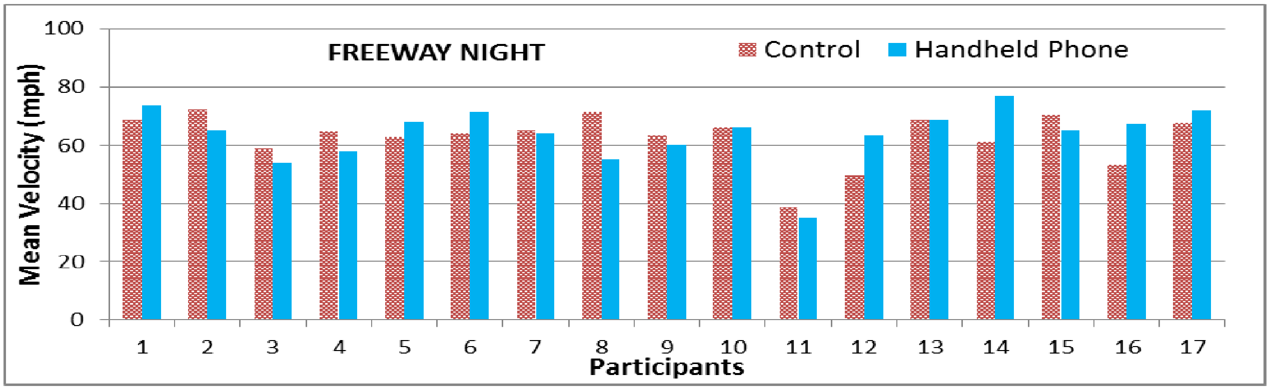

Figure B2-4

Speed profile for Control vs. Handheld Phone for freeway-night environment

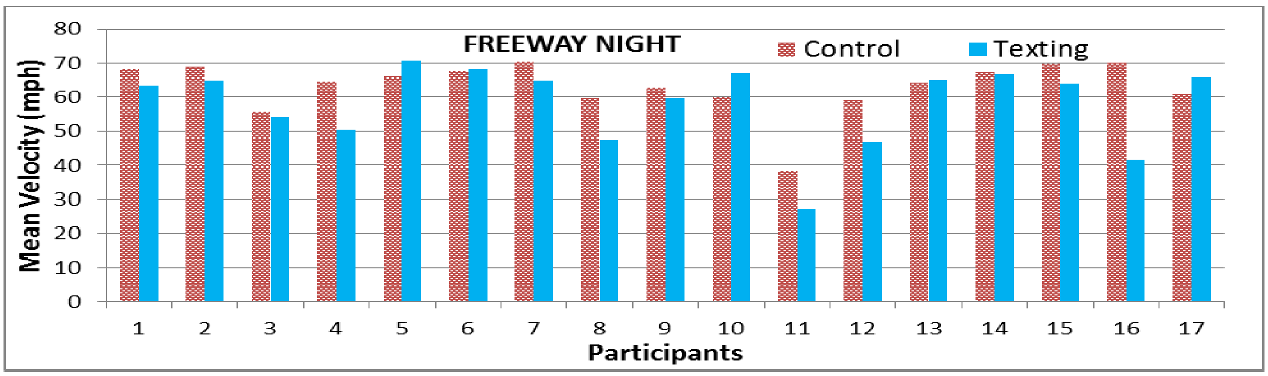

Figure B2-5

Speed profile for Control vs. Texting for freeway-night environment

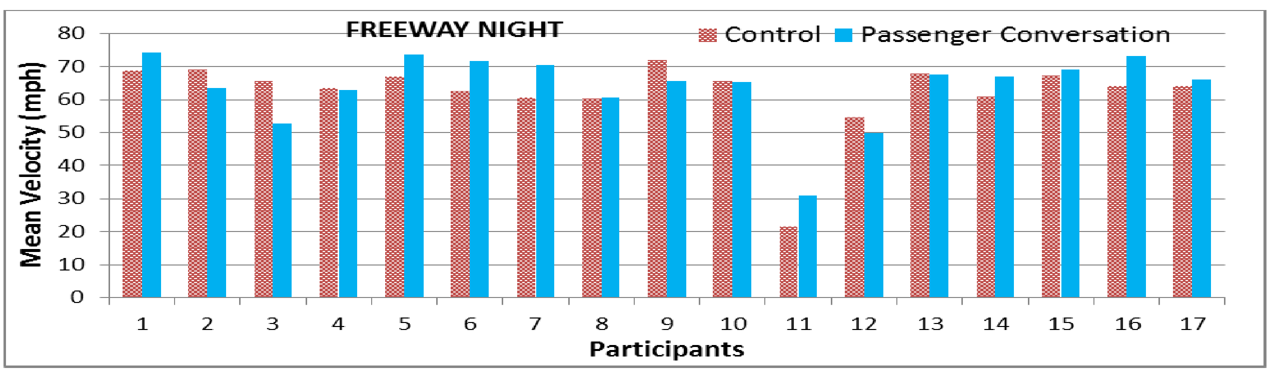

Figure B2-6

Speed profile for Control vs. Passenger Conversation for freeway-night environment

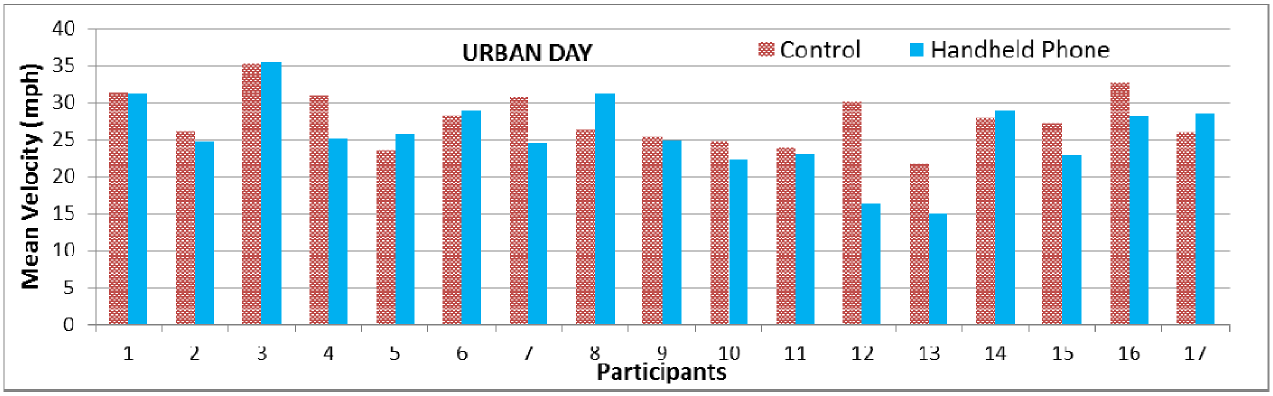

Figure B2-7

Speed profile for Control vs. Handheld Phone for urban-day environment

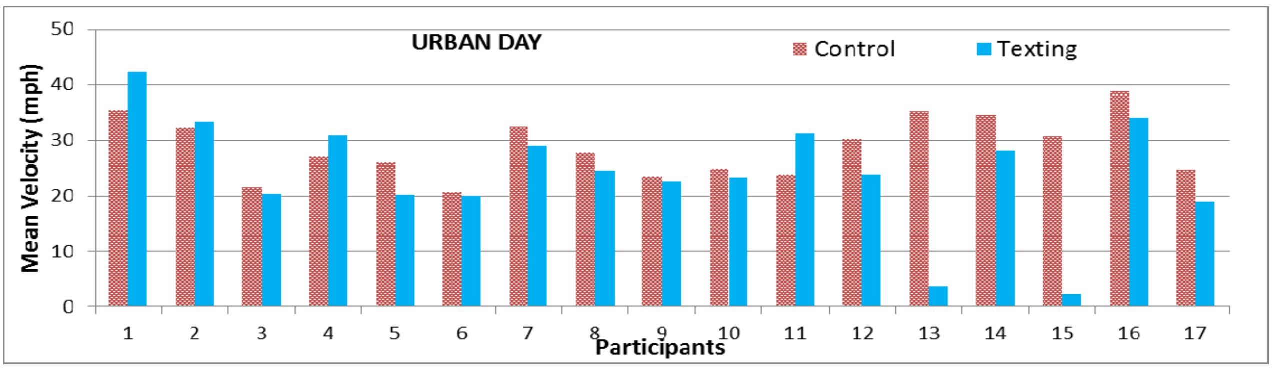

Figure B2-8

Speed profile for Control vs. Texting for urban-day environment

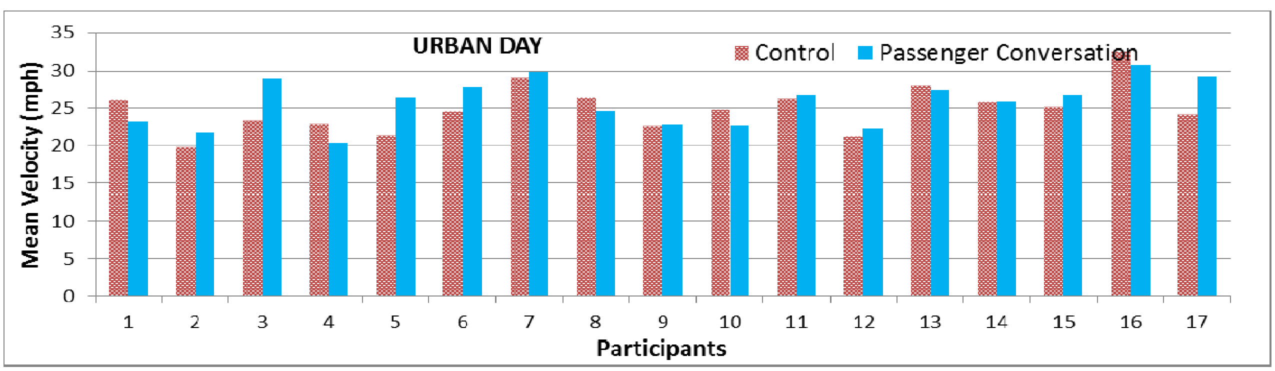

Figure B2-9

Speed profile for Control vs. Passenger Conversation for urban-day environment

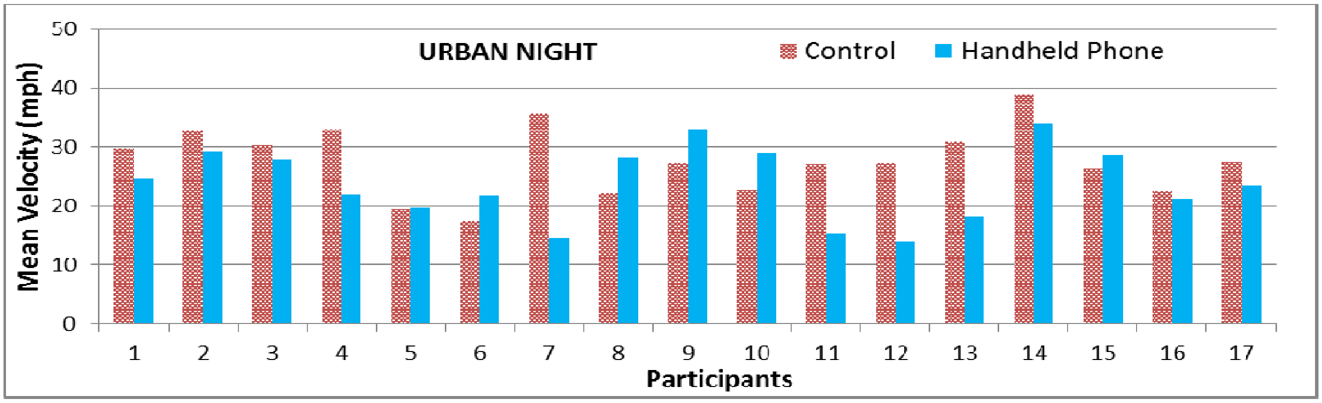

Figure B2-10

Speed profile for Control vs. Handheld Phone for urban-night environment

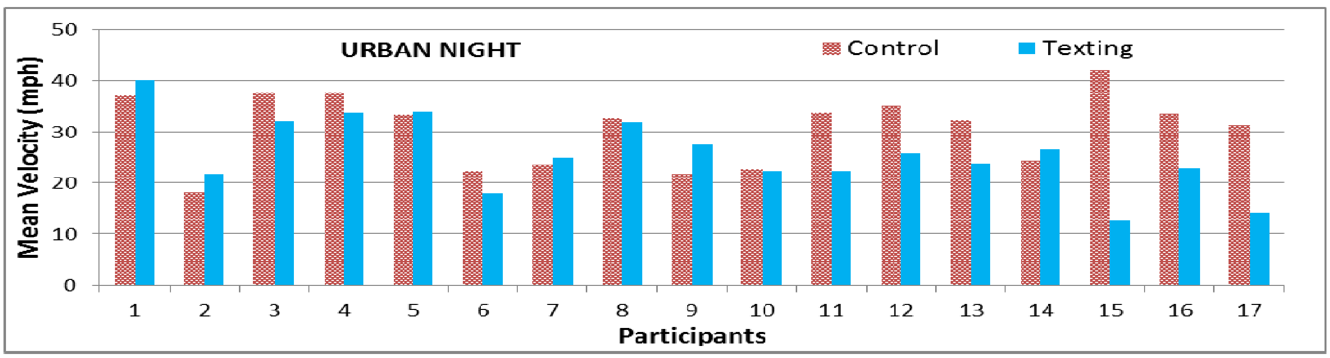

Figure B2-11

Speed profile for Control vs. Texting for urban-night environment

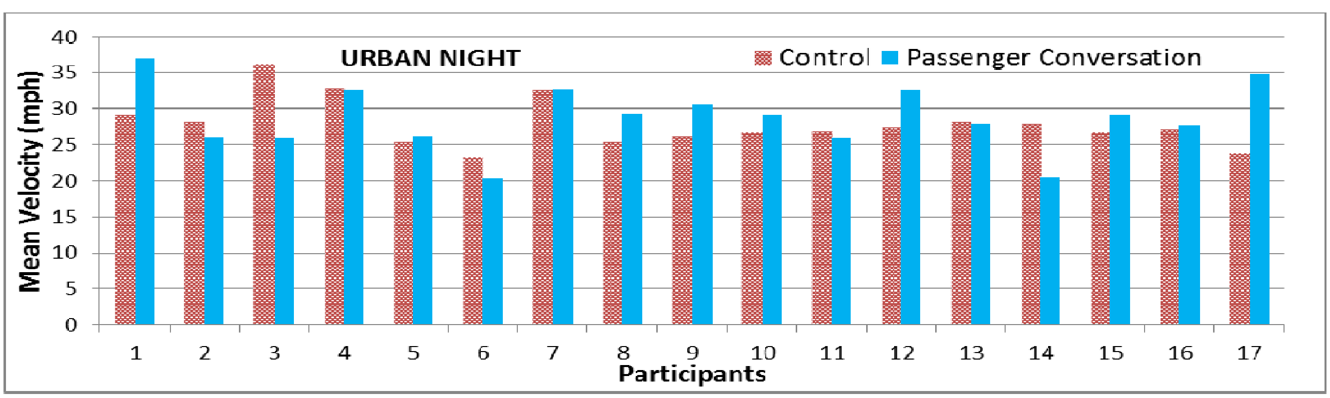

Figure B2-12

Speed profile for Control vs. Passenger Conversation for urban-night environment

Appendix B3 – Weather Condition Factor

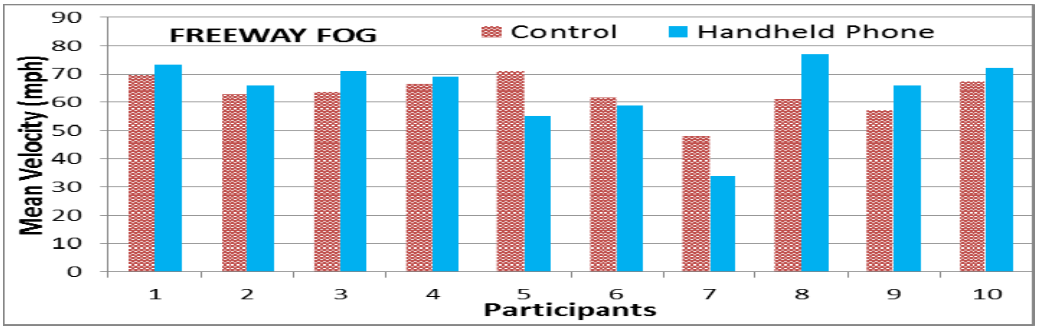

Figure B3-1

Speed profile for Control vs. Handheld Phone for freeway-fog condition

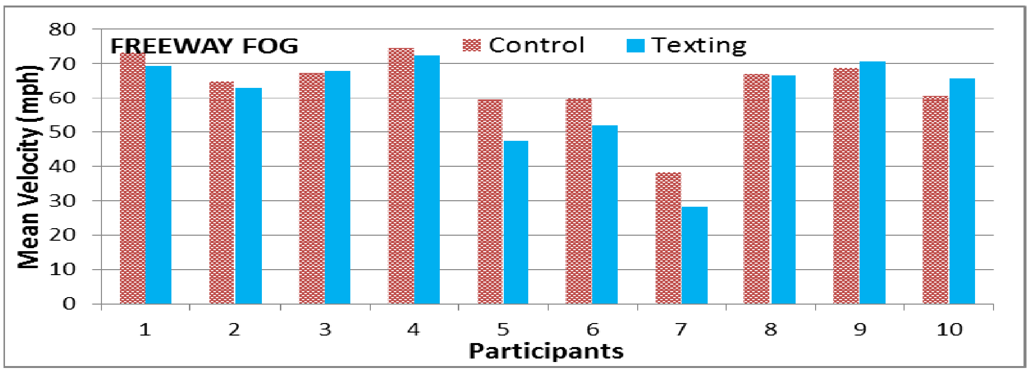

Figure B3-2

Speed profile for Control vs. Texting for freeway-fog condition

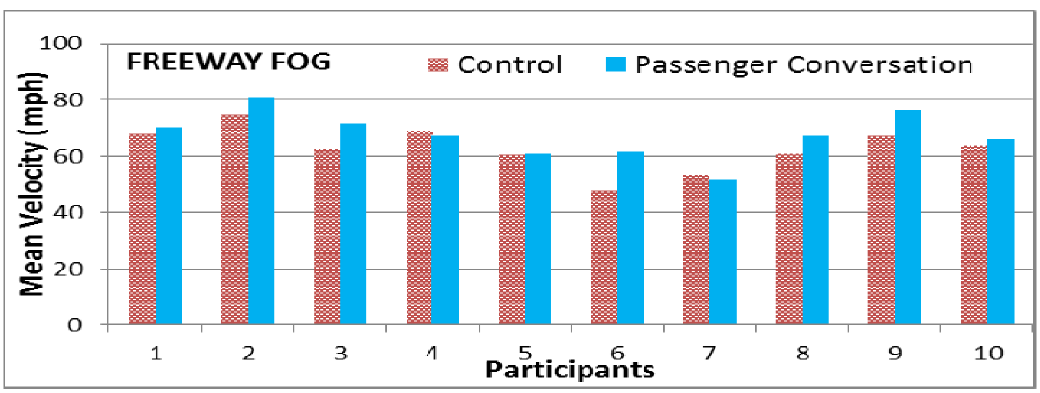

Figure B3-3

Speed profile for Control vs. Passenger Conversation for freeway-fog condition

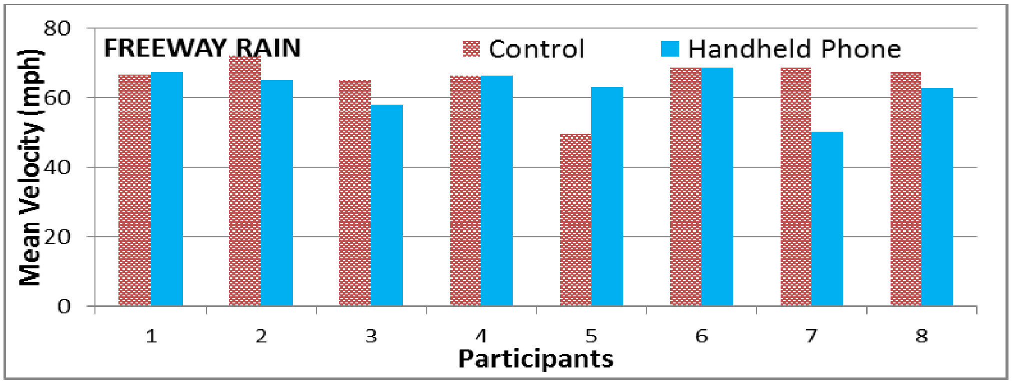

Figure B3-4

Speed profile for Control vs. Handheld Phone for freeway-rain condition

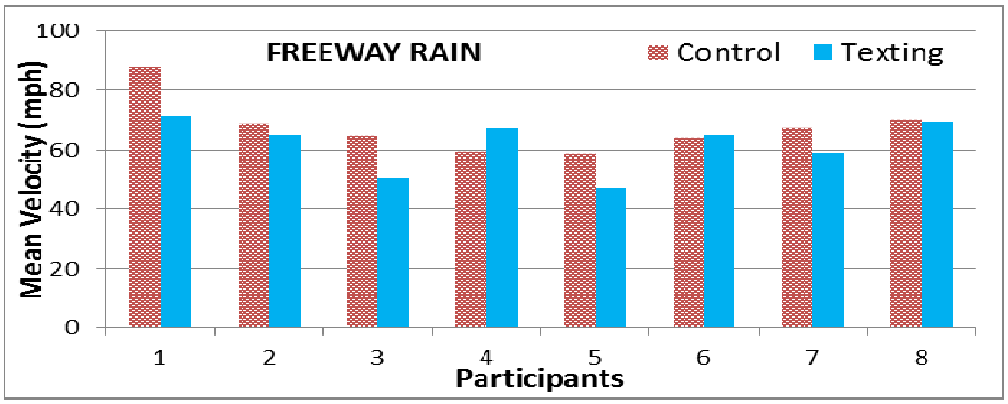

Figure B3-5

Speed profile for Control vs. Texting for freeway-rain condition

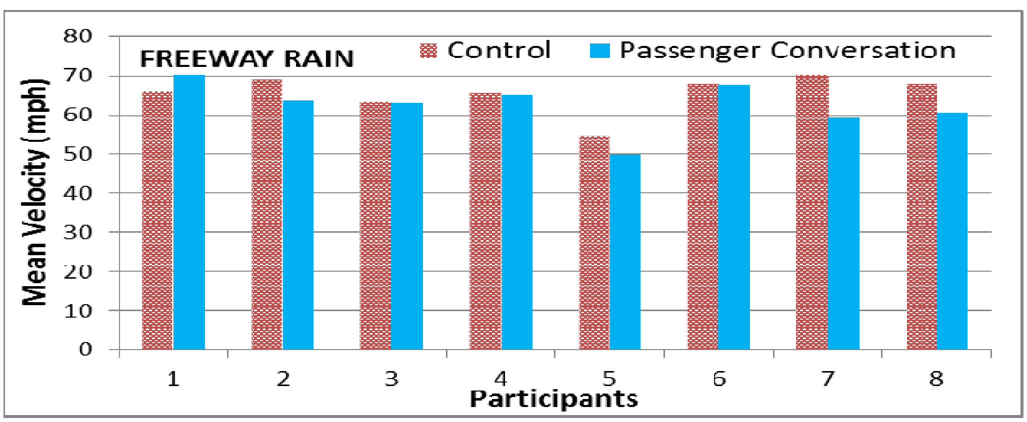

Figure B3-6

Speed profile for Control vs. Passenger Conversation for freeway-rain condition

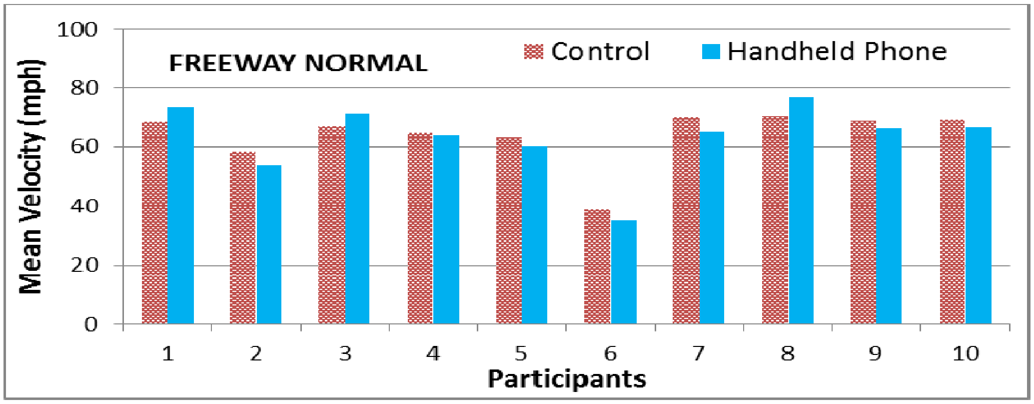

Figure B3-7

Speed profile for Control vs. Handheld Phone for freeway-normal condition

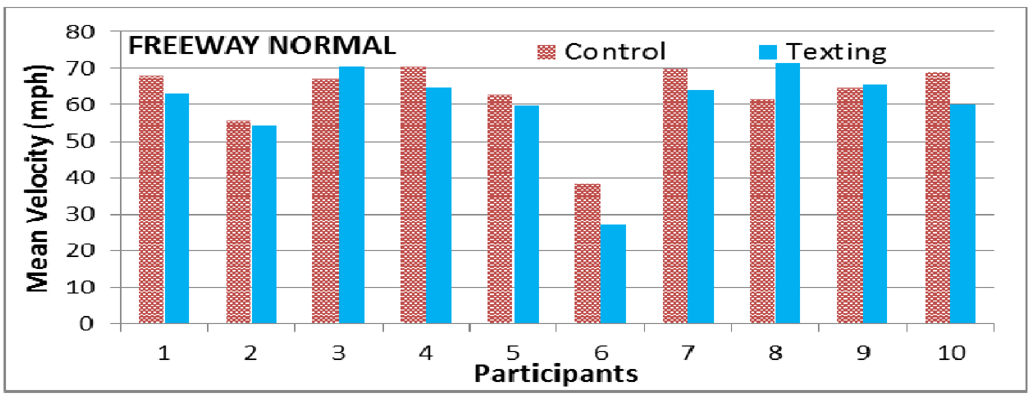

Figure B3-8

Speed profile for Control vs. Texting for freeway-normal condition

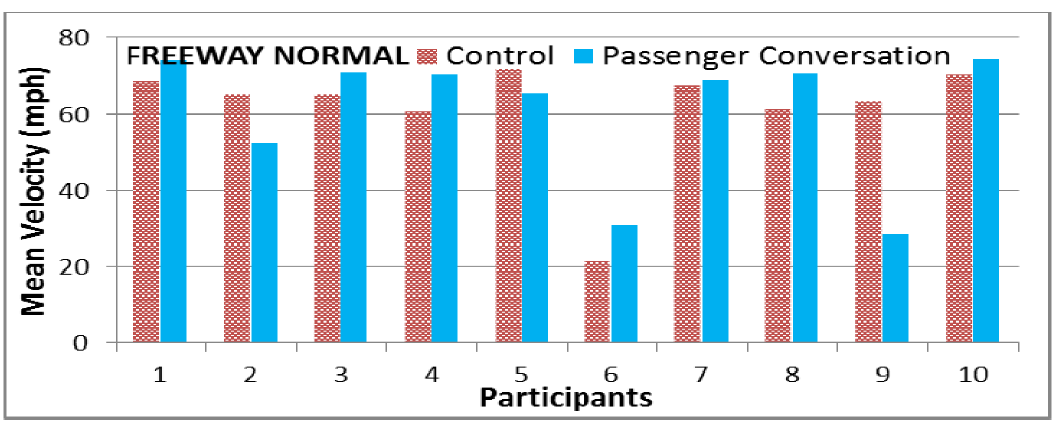

Figure B3-9

Speed profile for Control vs. Passenger Conversation for freeway-normal condition

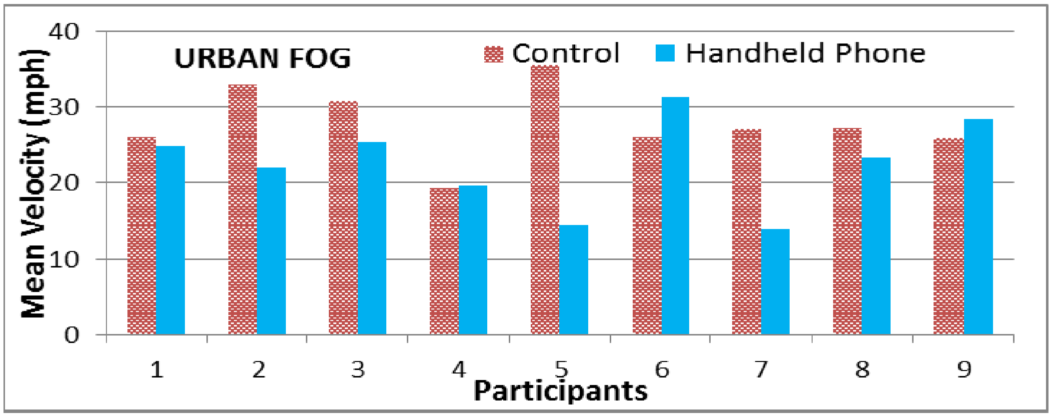

Figure B3-10

Speed profile for Control vs. Handheld Phone for urban-fog condition

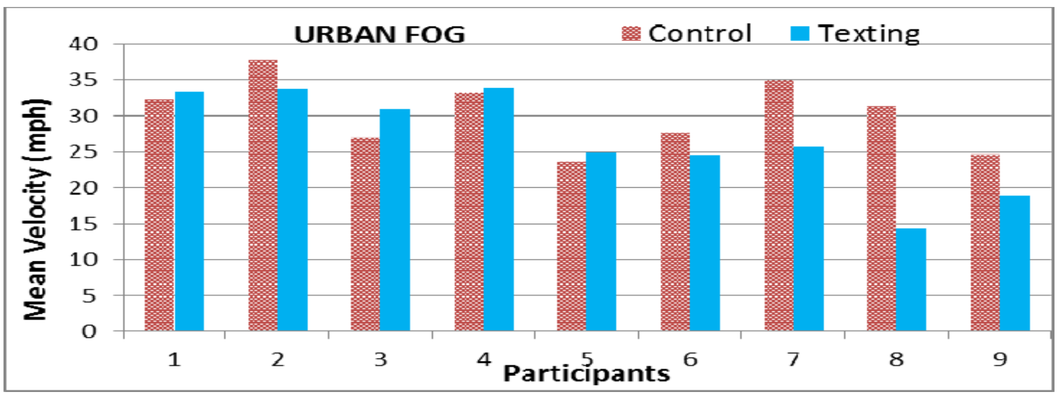

Figure B3-11

Speed profile for Control vs. Texting for urban-fog condition

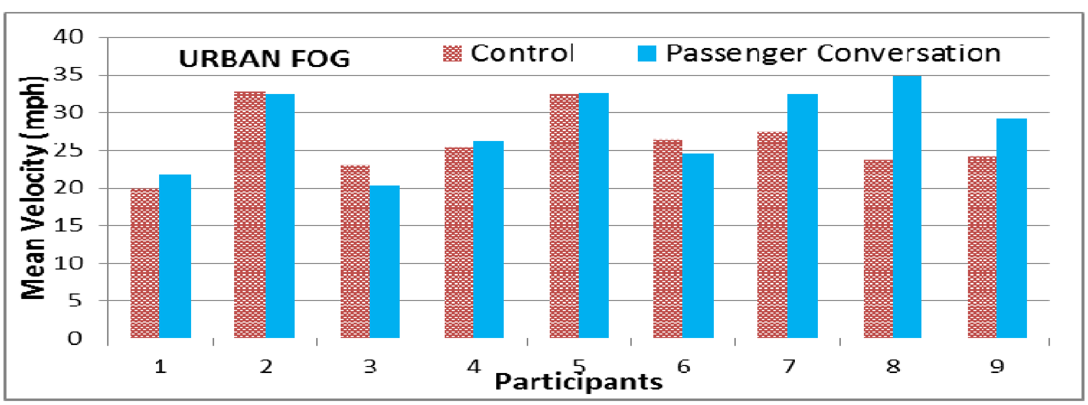

Figure B3-12

Speed profile for Control vs. Passenger Conversation for urban-fog condition

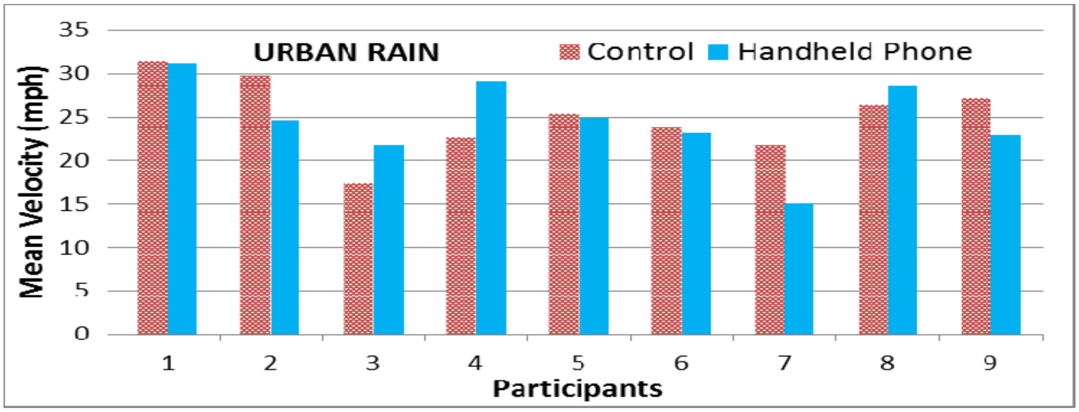

Figure B3-13

Speed profile for Control vs. Handheld Phone for urban-rain condition

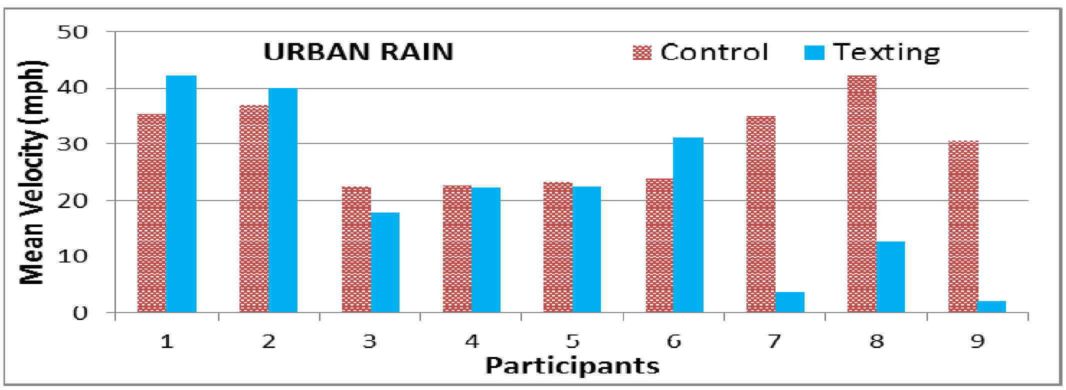

Figure B3-14

Speed profile for Control vs. Texting for urban-rain condition

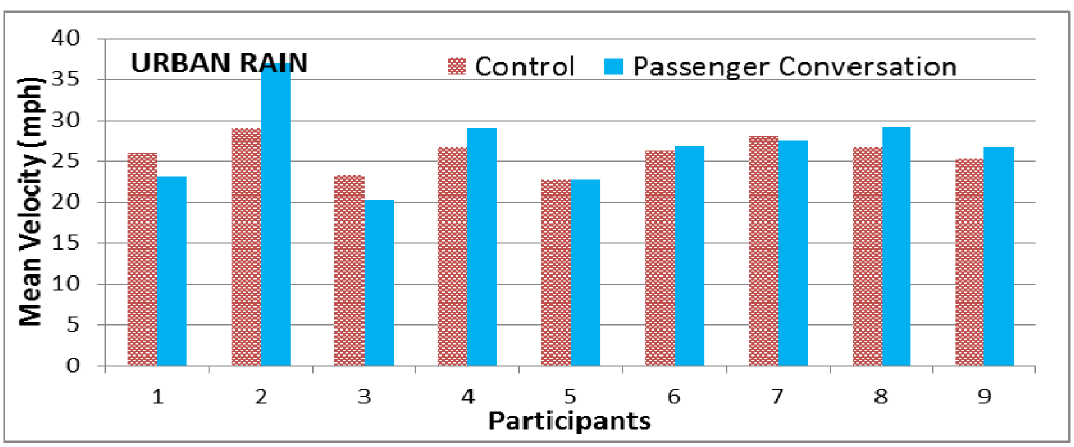

Figure B3-15

Speed profile for Control vs. Passenger Conversation for urban-rain condition

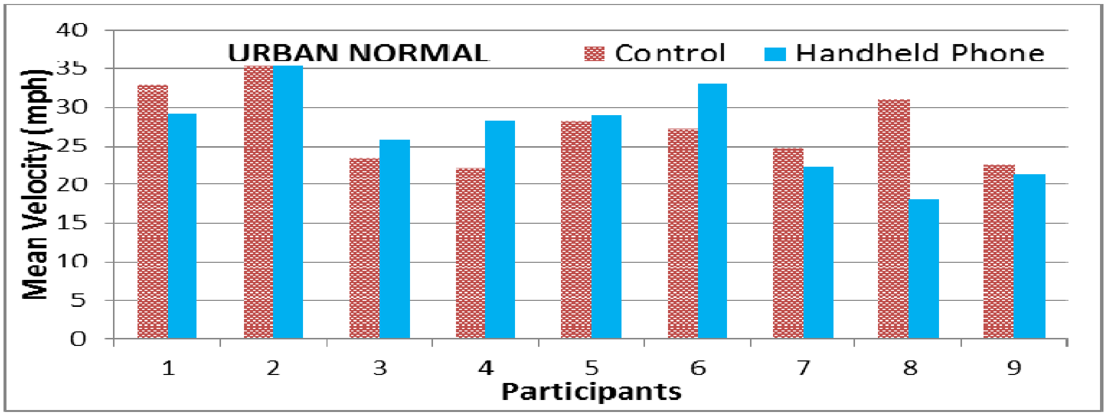

Figure B3-16

Speed profile for Control vs. Handheld Phone for urban-normal condition

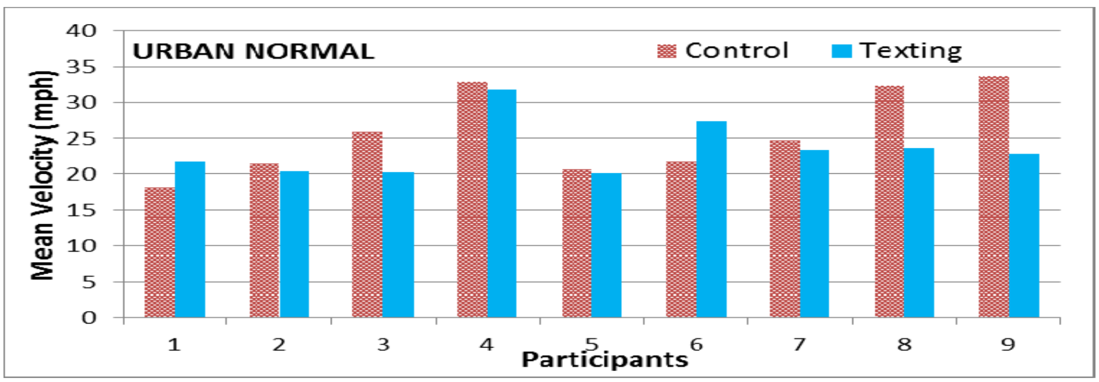

Figure B3-17

Speed profile for Control vs. Texting for urban-normal condition

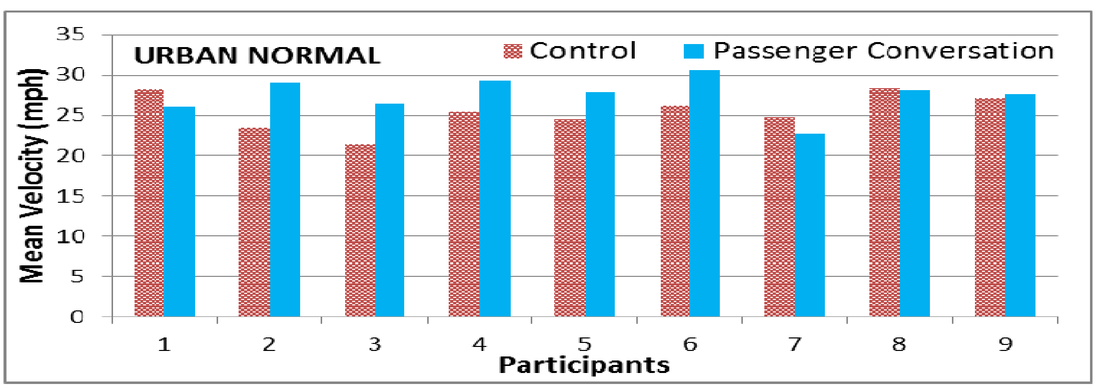

Figure B3-18

Speed profile for Control vs. Passenger Conversation for urban-normal condition

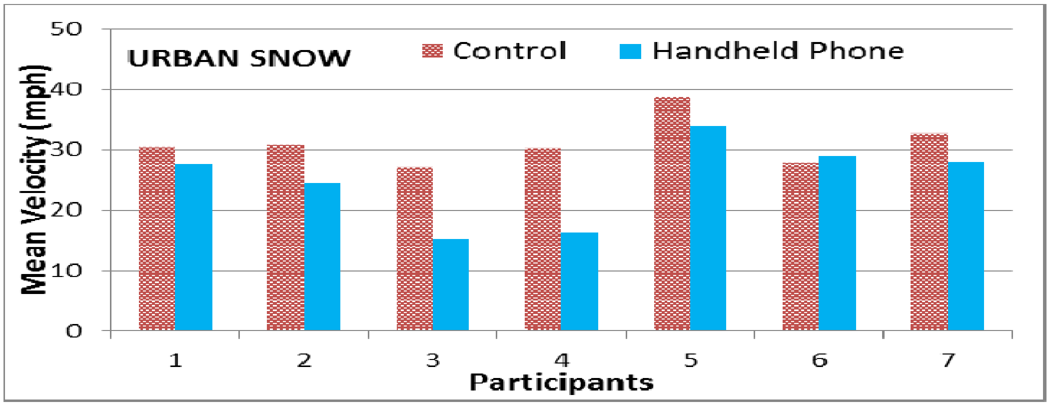

Figure B3-19

Speed profile for Control vs. Handheld Phone for urban-snow condition

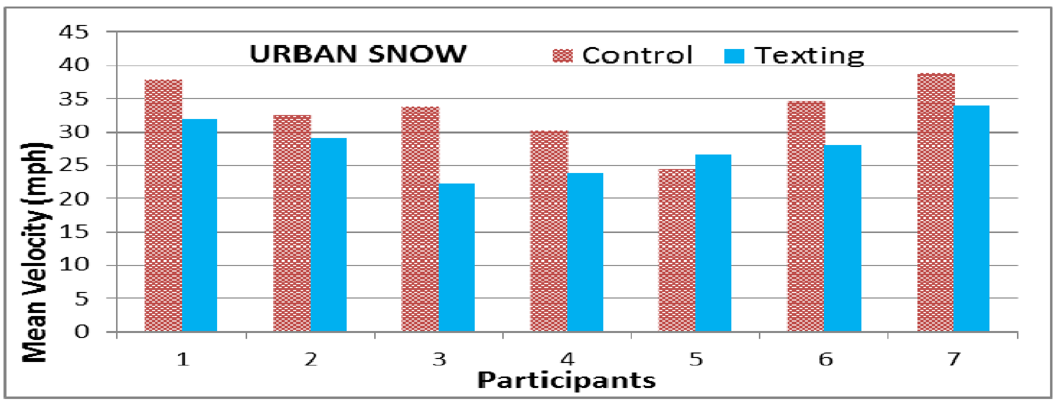

Figure B3-20

Speed profile for Control vs. Texting for urban-snow condition

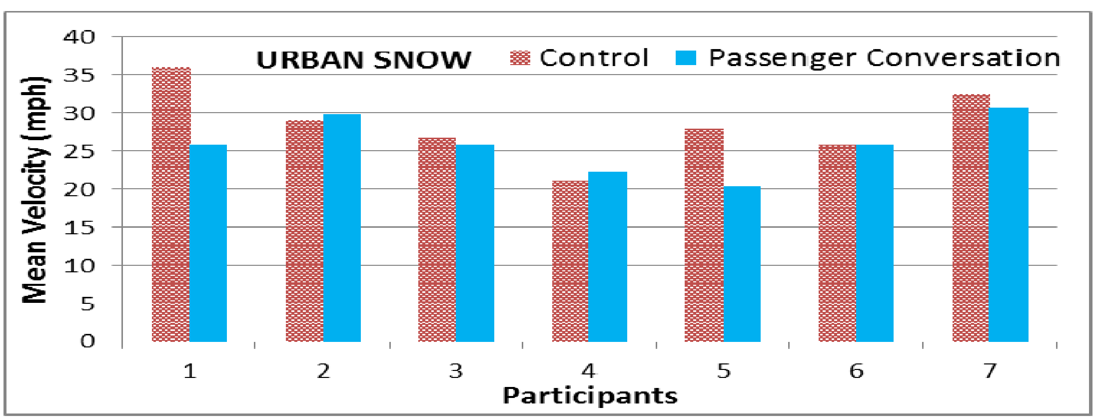

Figure B3-21

Speed profile for Control vs. Passenger Conversation for urban-snow condition

APPENDIX C (CHI-SQUARE VALUES FOR F-TEST)

This appendix shows the Chi-square values obtained for the different factors that were investigated to find which factor produced the larger deviations from the respective control drives. The Chi-square value is a number that adds up all the discrepancies between the control and treatment distributions. Greater values therefore suggest distributions that are farther apart.

			REDUCED LATERAL CONTROL			REDUCED LONGITUDINAL CONTROL		
			Handheld Phone Conversation	Texting	Front Seat Passenger Conversation	Handheld Phone Conversation	Texting	Front Seat Passenger Conversation
		Overall Effect	0.574	278.277	39.73	0.3815	66.7681	1.0467
Age		< 25 years	1.1147	13.3832	49.8299	0.175	58.9019	4.3691
		≥ 25 years	1.5778	362.623	4.1558	0.0628	24.23	11.972
Gender		Female	62.5332	33.1129	50.5964	5.2793	19.9665	3.7668
		Male	41.7221	275.39	10.4372	3.7897	55.9757	0.0053
Environr		Freeway	37.8355	342.223	3.2289	191.7832	301.9532	7.8498
		Urban	27.9046	46.6733	87.9744	51.4925	44.7895	35.0734
Time of Day	Freeway	Day	49.8421	60.5085	9.0944	120.4526	131.4076	34.0968
		Night	5.7752	262.04	13.1785	64.9981	168.7387	126.0452
	Urban	Day	25.3103	51.0954	7.5358	19.4223	29.9185	7.729
		Night	209.099	13.1554	89.2422	25.0334	14.5951	33.5148
Weather	Freeway	Fog	11.7043	226.304	8.8131	213.5439	41.2383	107.4683
		Normal	6.8514	75.7521	26.053	1.2549	232.1643	5.1518
		Rain	1.9084	19.8066	11.8685	42.3111	14.5089	74.1385
		Snow	3.5356	51.5133	14.127	460.7169	47.1865	2.7438
	Urban	Fog	6.7053	94.9729	14.2997	48.196	17.0617	54.6587
		Normal	13.5274	2.2543	26.432	0.5244	0.158	33.7719
		Rain	159.2639	0.0036	119.9089	1.3101	0.3344	11.2139
		Snow	107.7724	54.2897	15.3961	108.4151	195.8379	42.4993

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