8-2015

Analysis of Distractions for Teenage Drivers Utilizing a Car Simulator

Ali Mohammadhashemi
University of Tennessee - Knoxville, amohamm7@vols.utk.edu

To the Graduate Council:

I am submitting herewith a thesis written by Ali Mohammadhashemi entitled "Analysis of Distractions for Teenage Drivers Utilizing a Car Simulator." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

Rupy Sawhney, Major Professor

We have read this thesis and recommend its acceptance:

Robert Mee, Anahita Khojandi

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Analysis of Distractions for Teenage Drivers Utilizing a Car Simulator

A Thesis Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Ali Mohammadhashemi

August 2015

Dedication

I dedicate my thesis to: my parents, Zahra Lashgari and Hasan Mohammadhashemi, and my sister, Narges Mohammadhashemi for their unconditional love, support and encouragement throughout my life. I also dedicate this work to my wife, Leigh Anne Cutshaw who has been a source of encouragement during the challenge of graduate school life.

Acknowledgements

I want to say thank you to the people who have helped me reach the point where I am now. I am grateful to my advisor, Dr. Rapinder Sawhney for giving the opportunity to be a member of his research team and for his support and kindness over these years.

I am also grateful to my thesis committee members, Dr. Robert Mee and Dr. Anahita Khojandi for their contribution to this work. Dr. Mee provided me with valuable feedback and insightful suggestions. He gave a lot of his time to teach and guide me through the research.

I would like to give thanks to my kind and helpful friends at the department of Industrial and System Engineering, Kaveri Thakur and Gurudatt Sanil for their aid during the experiment. Also I am thankful to Sima Maleki, Vahid Ganji, Mostafa Ghafoori, and Isaac Atuahene for their support and availability.

Last, but not least, I would like to acknowledge my committee members, my parents, and my wife who have always supported and motivated me.

Abstract

An experiment was designed and implemented at the University of Tennessee to find the most important factors affecting teenager driving behavior. The factors included distraction, road condition, and gender. Response variables were standard deviation of velocity, standard deviation of lane position, and mean velocity. ANOVA and mixed model were used to determine if distractions, gender, and road condition affected response variables. Additionally, distractions were ranked based on their impact on the response variables' values. The participants were 22 teenage drivers (16-18 years old), driving in a Ford Focus simulated car. They were faced with 11 internal distractions.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction and General Information

Introduction

Motor vehicle crashes are the top two causes of injury or death during a person's lifetime, as illustrated in *Table 1* (Office of Statistics and Programming, 2011).

Table 1: Leading Causes of Unintentional Injury Death by Age Group, US, 2011

	Age Groups										
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Unintentional Suffocation 896	Unintentional Drowning 438	Unintentional MV Traffic 350	Unintentional MV Traffic 437	Unintentional MV Traffic 6,926	Unintentional Poisoning 7,652	Unintentional Poisoning 8,075	Unintentional Poisoning 10,379	Unintentional Poisoning 5,048	Unintentional Fall 22,901	Unintentional Poisoning 36,280
2	Homicide Unspecified 142	Unintentional MV Traffic 330	Unintentional Drowning 128	Suicide Suffocation 177	Homicide Firearm 3,825	Unintentional MV Traffic 5,569	Unintentional MV Traffic 4,425	Unintentional MV Traffic 5,240	Unintentional MV Traffic 4,184	Unintentional MV Traffic 6,225	Unintentional MV Traffic 33,783
3	Unintentional MV Traffic 93	Homicide Unspecified 181	Unintentional Fire/Burn 81	Homicide Firearm 107	Unintentional Poisoning 3,440	Homicide Firearm 3,271	Suicide Firearm 2,837	Suicide Firearm 4,100	Suicide Firearm 3,522	Unintentional Unspecified 4,630	Unintentional Fall 27,483
4	Homicide Other Spec., Classifiable 82	Unintentional Suffocation 144	Homicide Firearm 55	Unintentional Drowning 107	Suicide Firearm 2,168	Suicide Firearm 2,740	Suicide Suffocation 1,959	Suicide Suffocation 2,062	Unintentional Fall 2,141	Suicide Firearm 4,526	Suicide Firearm 19,990
5	Unintentional Drowning 52	Unintentional Fire/Burn 130	Unintentional Suffocation 34	Suicide Firearm 91	Suicide Suffocation 1,898	Suicide Suffocation 2,055	Homicide Firearm 1,718	Suicide Poisoning 1,946	Suicide Poisoning 1,411	Unintentional Suffocation 3,402	Homicide Firearm 11,068
6	Undetermined Suffocation 40	Homicide Other Spec., Classifiable 92	Unintentional Other Land Transport 31	Unintentional Other Land Transport 47	Unintentional Drowning 543	Suicide Poisoning 816	Suicide Poisoning 1,280	Unintentional Fall 1,368	Suicide Suffocation 1,107	Adverse Effects 1,628	Suicide Suffocation 9,913
7	Unintentional Unspecified 28	Unintentional Pedestrian, Other 88	Unintentional Natural/ Environment 28	Unintentional Suffocation 43	Homicide Cut/Pierce 395	Undetermined Poisoning 594	Undetermined Poisoning 655	Homicide Firearm 1,147	Unintentional Suffocation 644	Unintentional Poisoning 1,581	Suicide Poisoning 6,564
8	Unintentional Fire/Burn 24	Unintentional Struck by or Against 56	Unintentional Firearm 16	Unintentional Fire/Burn 42	Suicide Poisoning 349	Homicide Cut/Pierce 447	Unintentional Fall 524	Undetermined Poisoning 952	Homicide Firearm 546	Unintentional Fire/Burn 1,073	Unintentional Suffocation 6,242
9	Homicide Suffocation 23	Homicide Firearm 48	Unintentional Pedestrian, Other 16	Unintentional Poisoning 35	Undetermined Poisoning 252	Unintentional Drowning 442	Unintentional Drowning 414	Unintentional Suffocation 536	Unintentional Fire/Burn 522	Unintentional Natural/ Environment 825	Unintentional Unspecified 5,871
10	Unintentional Natural/ Environment 21	Unintentional Natural/ Environment 40	Two Tied* 15	Unintentional Other Transport 32	Unintentional Fall 205	Unintentional Fall 279	Homicide Cut/Pierce 317	Unintentional Drowning 479	Unintentional Unspecified 496	Suicide Poisoning 751	Unintentional Drowning 3,556

* Unintentional Other Transport and Unintentional Poisoning tied.

Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System.
Produced by: Office of Statistics and Programming, National Center for Injury Prevention and Control, CDC using WISQARS™.

Centers for Disease Control and Prevention
National Center for Injury Prevention and Control

In 2011, 4.5% or 9,000,000 drivers of 211,000,000 drivers in the United States were 19 and under; 360,000 were under 16 (The Federal Highway Administration 2013). The number of female and male drivers were almost the same for this age group (The Federal Highway Administration 2013). About 4,300 drivers involved in fatal crashes were ages 15-20, representing approximately 10% of all drivers. Traffic crashes are the leading cause of death for this age group. The number of male drivers involved in fatal crashes (3,032) was over represented compared to female drivers (1,314). Male drivers (1,424) were involved in more driver fatalities than female drivers (563) (NHTSA, 2011). Tennessee in 2011 was ranked 10^{th} out of all the states for fatalities in crashes involving young drivers (ages 15-20) (The Federal Highway Administration 2013). The factors related to these high accident rates are the following: risk-taking behavior, using distracting devices, night driving, driving with other teenage passengers, and driving under the influence of alcohol (Ferguson, 2003). Driver distraction is a significant contributor to road traffic accidents for teenagers as well as the rest of the population (Horberry, Anderson, Regan, Triggs, & Brown, 2006).

Background of the Problem

Teenage drivers have higher accident risks in comparison to other age groups (Jonah, Thiessen, & Au-Yeung, 2001). Rapidly evolving information technology is affecting cars and drivers. Cellphones, MP3 players, and other technologies are being used more in cars (Lee, 2007). The research of Neyens (2008) shows that 21.03% of sampled crashes were related to inattentive drivers. According to a study conducted by Lam (2002), age is a determining factor for distractions occurring inside the vehicle and for vehicle crash injuries. Teenage drivers' high fatality rate has been attributed to engaging in risky behavior, including being distracted while driving (Jonah et al., 2001; Olsen, Lerner, Perel, & Simons-Morton, 2005). One reason is that distractions reduce the ability to perceive and react quickly to changing traffic conditions. For example, Strayer and Drews (2004) showed in their driving simulation study that engaging in phone conversation resulted in slower reaction times and a twofold increase in rear-end collision.

Purpose of this Study

This research considered the impact of three factors on teenage driving: distractions, gender, and road condition. The distractions included tasks and activities such as plugging a cellphone in to charge and pulling up Facebook on the phone; answering/talking/hanging up a call; changing a radio station; texting; grooming; adjusting dashboard controls; using GPS; eating and drinking; talking with passenger; using cell phone (dialing/talking/hanging-up); and using a cell phone touch screen (e.g. Pandora app). New infotainment technologies have the potential to exacerbate or mitigate young drivers' risk of having crashes (Lee, 2007). This research attempts to create a great awareness of distractions' threat to teenage drivers by identifying factors and their impact on teenage driving behavior. In turn, strategies for new intervention can reduce teenage vehicle crashes.

Patel, Ball, and Jones (2008) noted that subjective ranking of the individual distractions' importance differs from objective measurement. For example, participants ranked distractions they were more familiar with as less dangerous than unfamiliar distractions. This study used objective ranking to overcome this problem.

In this study, distractions' influence was measured using performance metrics, such as mean velocity, standard deviation of lane position, and standard deviation of velocity. These measures were selected based on a comprehensive literature review, indicating that previous research focused on a maximum of two response variables.

Primary Research Questions

This research addresses the following questions:

1. Which of the following factors have statistically significant effects on mean velocity (involving 5 different road conditions)?
   - Gender
   - Distraction
   - Road Condition
2. Which of the following factors have statistically significant effects on standard deviation of velocity (involving 5 different road conditions)?
   - Gender
   - Distraction
   - Road Condition
3. Which of the following factors have statistically significant effects on Standard deviation of lane position (involving 5 different road conditions)?
   - Gender
   - Distraction
   - Road Condition
4. Given fixed road conditions and no events, which of the following factors have statistically significant effects on mean velocity?
   - Gender
   - Distraction
5. Given fixed road conditions and no events, which of the following factors have statistically significant effects on standard deviation of velocity?
   - Gender
   - Distraction
6. Given fixed road conditions and no events, which of the following factors have statistically significant effects on standard deviation of lane position?
   - Gender
   - Distraction
7. Given fixed road conditions and events are introduced, which of the following factors have statistically significant effects on mean velocity?

- Gender
- Distraction

8. Given fixed road conditions and events are introduced, which of the following factors have statistically significant effects on standard deviation of velocity?
   - Gender
   - Distraction
9. Given fixed road conditions and events are introduced, which of the following factors have statistically significant effects on standard deviation of lane position?
   - Gender
   - Distraction
10. Given fixed road conditions and events are introduced, which of the following factors have statistically significant effects on coefficient of variation of lane position?
    - Gender
    - Distraction
11. Given different road conditions and events, what is the ranking of distractions' effect on teenage driving performance when driving performance is measured by mean velocity, coefficient of variation of headway distance, standard deviation of velocity and standard deviation of lane position?

Experiment Setup

A Design of Experiment (DOE) was used to establish the structure for evaluating the above questions. A car simulator at the University of Tennessee was used in conducting the experiment. *Figure 1* presents an overview of the experiment, and *Table 2* shows the specific experiment conducted. This research considered the effect of distraction, gender and road condition on driving performance discussed above.

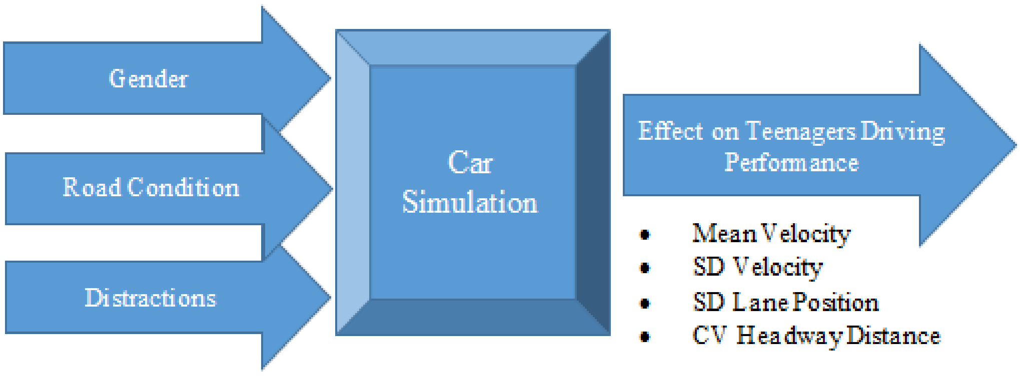


Figure 1:Experiment

Table 2:Experiment Scenarios

Scenarios			Speed limit	Road Type	Traffic	Weather	Curvy	Event	Factors	Response Variables	Analysis
No Event	All Road Conditions	Road Segment 1 Road Segment 2 Road Segment 3 Road Segment 4 Road Segment 5	24.44 11.11 11.11 13.33 11.11	Highway Residential Urban Urban Rural	Average Average Average Average High	Clear Clear Rainy Clear Snowy	Slightly curvy Straight Straight Straight Curvy	-	Gender, Distraction, & Road Condition	Mean Velocity SD Velocity SD Lane Position	Mixed Model (n=110 for each response variable)(Driver: random)
	Individual Road Condition	Road Segment 1	24.44	Highway	Average	Clear	Slightly curvy	-	Gender & Distraction	Mean Velocity	ANOVA (n=22 for each road segment and each response variable)
		Road Segment 2	11.11	Residential	Average	Clear	Straight	-			
		Road Segment 3	11.11	Urban	Average	Rainy	Straight	-		SD Velocity	
		Road Segment 4	13.33	Urban	Average	Clear	Straight	-			
		Road Segment 5	11.11	Rural	High	Snowy	Curvy	-		SD Lane Position	
Event	Individual Road Condition	Road Segment 1	24.44	Highway	Average	Clear	Slightly curvy	Dog	Gender & Distraction	Mean Velocity	ANOVA (n=22 for each response variable and road segment 1&2 and n=15 for each response variable and road segment 4)
		Road Segment 2	11.11	Residential	Average	Clear	Straight	Kids		SD Velocity	
		Road Segment 4	13.33	Urban	Average	Clear	Straight	Ambulance		SD Lane Position CV Headway Distance	
	All Road Conditions	Road Segment 1 Road Segment 2 Road Segment 4	24.44 11.11 13.33	Highway Residential Urban	Average Average Average	Clear Clear Clear	Slightly curvy Straight Straight	Dog Kids Ambulance	Distraction	Rank (Mean Velocity) Rank (SD Velocity) Rank (SD Lane Position) Rank (CV Headway Distance)	Mixed Model: (n=4x[22+22+15]=236) (Driver: random)

Assumptions

The following assumptions were made:

- Drivers were random effect variables in the model, meaning they represent a larger population of drivers.
- The experimental design considered distraction, road condition, and gender effects on response variables.
- A simulation's artificial nature may encourage the driver to maximize performance as the consequences are not representative of real life. Drivers want to perform well, and simulation is unable to evaluate a distraction countermeasure over a prolonged period of time (Kircher, 2007).
- This experiment tried to capture three factors with limited data collected and replications performed due to cost. The experiment involved 22 drivers, leading to extra costs with minimum benefits for this project.

Analytical Framework

This research used the following analysis methods:

1. ANOVA for individual road condition and mixed model for all road conditions were used to find important factors of driving performance and significant levels for each factor. With so many tests, the type I error was increased; therefore, some levels are incorrectly found to be statistically significant due to type I error.
2. The motivation of the mixed model ranking was to reduce type I error. It considered all distractions and road conditions in the presence of an event for combined response variables. Distractions were ranked based on their effect.

Outline of the Study

The remainder of this thesis is organized as follows: Chapter Two presents a comprehensive literature review for each factor affecting driving performance (distraction, gender, and road condition). Chapter Three describes the experiment setup, including experimental procedures and data collection. Chapter Four presents results of the ANOVA, mixed model, and ranking analysis. Finally, Chapter Five discusses this study's contributions and offers recommendations for future studies.

Chapter 2
Literature Review

Distractions Categories

Driver distraction may be characterized as any activity that takes a driver's attention away from the task of driving, resulting in reduction of awareness, decision making, or performance (Ranney, 2001). The boundary of this definition of distraction is better defined by the following: "Distractions exclude pre-existing conditions, including impairment by alcohol or drugs, fatigue, and psychological state; however, any of these can potentially make it easier for a driver to be distracted or can change the effect of a distraction" (Kircher, 2007). These distractions can be from any electronic distraction within the car such as navigation system and cell phone or it can be interacting with passengers (National Highway Traffic Safety Administration, 2010).

Four distinct categories of distraction exist, but more than one can be active at a time (Kircher, 2007):

- Auditory (e.g., responding to ringing cell phone or listening to a conversation).
- Biomechanical (e.g., adjusting CD player, taking hands off the wheel).
- Visual (e.g., looking away from the road or reading a map). This category seems to have more of a safety effect than cognitive and auditory distraction (Horberry et al., 2006).
- Cognitive (e.g. lost in thought or "looking" but not "seeing"). For example, the cognitive distraction from a text message is similar to that of active listening (talking to somebody); the person must comprehend the message, retain its information, and develop a response. Anderson (2012) focused only on cognitive distractions and found that complex tasks requiring math and memorization pose the highest level of danger. The National Highway Traffic Safety Administration (NHTSA) (2013) published a report focusing on both visual and manual distractions. Among drivers involved in crashes, internal distraction was more important than cognitive distraction. The most common internal distraction is conversing with a passenger (NHTSA 2010).

Effect of Distractions on Driving Performance

The National Highway Traffic Safety Administration (2010) estimates that 5,474 people were killed and nearly 450,000 were injured in crashes involving a distracted driver in 2009. Police accident reports show that up to 25% of crashes involved some degree of driver distraction (Jing-Shiarn Wang, 1996; Stutts & Association, 2001). In 2001, 12% of the tow-away crashes resulted from distraction; and of this 12%, 30% of the distractions were by a person, an object, or an event outside the car; 35% were by something inside the car; the rest were unknown, as illustrated in *Figure 2* (Kircher, 2007). As most drivers will not incriminate themselves regarding distractions, the true number is likely higher (Neyens, 2007).

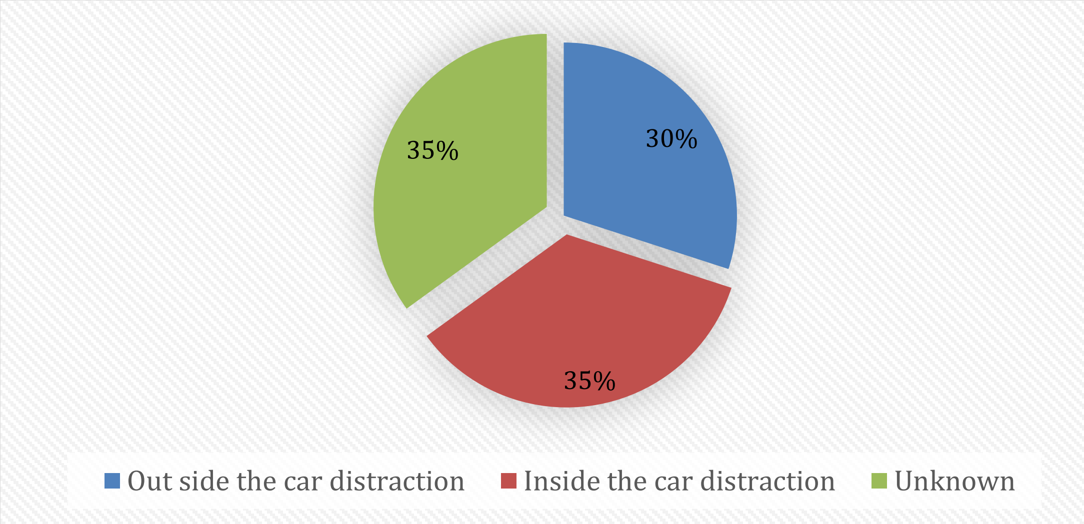


Figure 2: Distraction Type for Towaway Crashes

Researchers say cellphone conversations cause inattention blindness (NSC, 2012). Using a cellphone while driving delays a driver's reaction as much as having a blood-alcohol concentration at the legal limit of 0.08%. According to the American Automobile Association, cellphone use increases the risk of crashing fourfold (McEvoy et al., 2005). Other studies indicate that distractions, such as listening to music and conversing with others, can be just as dangerous (Anderson, 2012). Among distracted drivers 11.4% of crashes is caused by adjusting the radio and CD player, and 1.5% of crashes is caused by mobile phone use (Stutts et al., 2001).

NHTSA (2010) published the role of each internal distraction among the estimated 2,188,970 crashes in *Figure 3*. The most recorded factor was conversation with passenger with 16% share. This percentage was true irrespective of driver age and gender, and of weather and traffic flow conditions. Therefore, conversation with passenger cannot be concluded as the cause of a crash. Phone use (texting, dialing/hanging up, conversing on the phone) is the second-most recorded factor, causing 3.4% of the crashes. In 70% of crashes, no distraction came from an internal source. The National Safety Council (NSC) (2012) estimates that one in four motor vehicle crashes involves cellphone use. NSC doesn't recommend hands-free devices while driving because they do not eliminate cognitive distraction. Also, according to the NSC, vehicle manufacturers are including more wireless and voice-recognition communications technologies in vehicles, but their impact on distraction has not been studied.

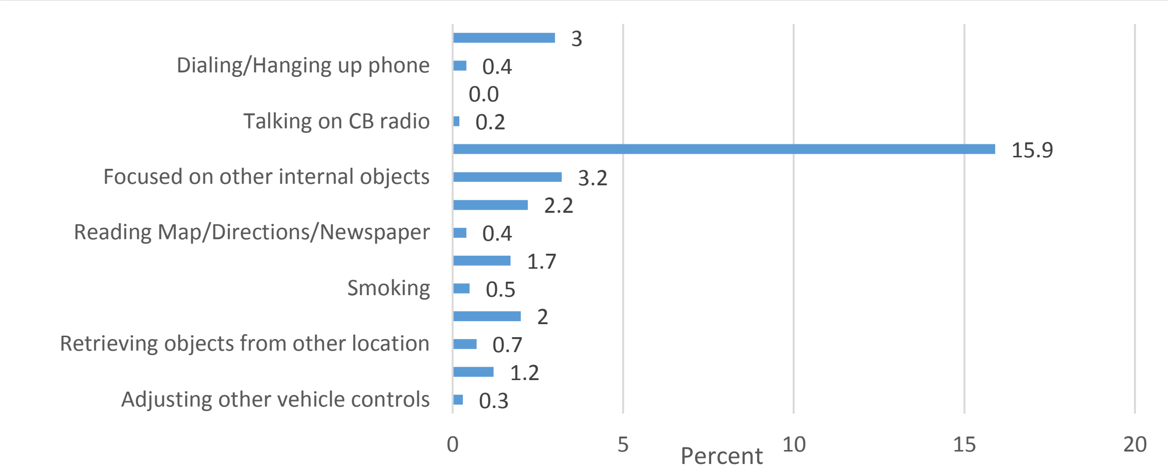


Figure 3: Role of Each Internal Distraction Among 2,188,970 Crashes (NHTSA, 2010)

Horrey, Lesch, and Garabet (2008) used an instrumented vehicle to test the difference between hand-held and hands-free phone use while driving. Burns, Parkes, Burton, Smith, and Burch (2002) found that drivers using hand-held mobile phone were on average 50% slower to respond to hazards than when driving without using a phone. Adjusting a radio or a cassette or CD player was found to be one of the major causes of distraction-related accidents. Relatively low-tech tasks, such as using a vehicle's radio, have safety implications (Horberry et al., 2006). Cellphones are associated with cognitive, auditory, biomechanical, and visual distractions (Neyens, 2007). According to the National Safety Council's (2012) data, drivers talking on cellphones were involved in more crashes; and an estimated minimum of 160,000 crashes involved texting or emailing, versus 1.1 million crashes involving talking on cellphones.

Risk of Distractions for Teenage Drivers

On a per-mile basis, young drivers aged 16 to 19 are over represented in severe crashes by a factor of 10, compared with adult drivers aged 40 to 50 (McKnight & McKnight, 2003). Ferguson (2003) found that younger drivers are overrepresented in crashes involving excessive speed, curve, alcohol, fatigue, distraction, and passengers. Westlake and Boyle (2012) concluded that not all teenagers place themselves at risk; however, a subgroup of teenage drivers often engages in distracting activities. Westlake and Boyle (2012) showed that teenage drivers who were frequently engaged in distracting activities (20% of 1603 sample size) and teenage drivers who were moderately engaged in distracting activities (31% of 1603 sample size) were more likely to have a crash.

With increasing driver age, the tendency is for distractions to decrease from internal sources. Older adults, in some cases are able to offset age-related declines through increased driving experience and improved skills (Horrey et al., 2008). The youngest and most inexperienced drivers are most at risk as illustrated in *Figure 4*, with 16% of all distracted driving crashes involving drivers under age 20 (Department of Transportation, 2010). Also, Strutts et al. (2001) found that young drivers were more distracted by adjusting a radio or a cassette or CD player among the under 20 year-olds; 20-29 year-olds were distracted by other occupants in the car; and those age 65 and older were distracted by external objects and events.

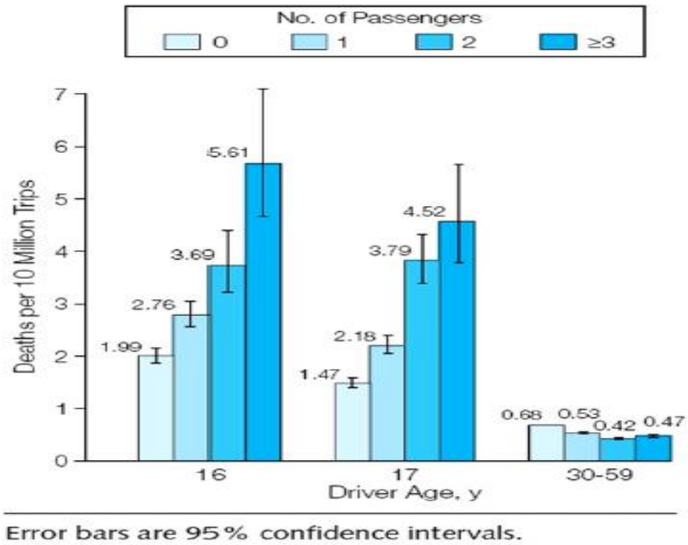


Figure 4: Age and Death Accidents: More Death With More Peer Passengers

Each distraction's risks are determined by not only the distraction's type and name but also the frequency, duration (Kircher, 2007), familiarity, voluntariness (Slovic, 2000), and overconfidence in safety (Horrey et al., 2008). Teenagers tend to be overconfident in their driving ability and to underestimate specific driving situations' danger (Finn & Bragg, 1986). Therefore, this research study considered this age group.

Effect of Gender and Road Condition on Driving Performance:

Regarding the gender factor, male teens have higher rates of accidents in both nonfatal-injury crashes and fatal crashes (Shope & Bingham, 2008). According to the Insurance Institute for Highway Safety (2013), teenage drivers are more involved in fatal accidents compared to age group 20-24, age group 25-29, age group 39-59, and age group 60-69, as shown in *Figure 5*.

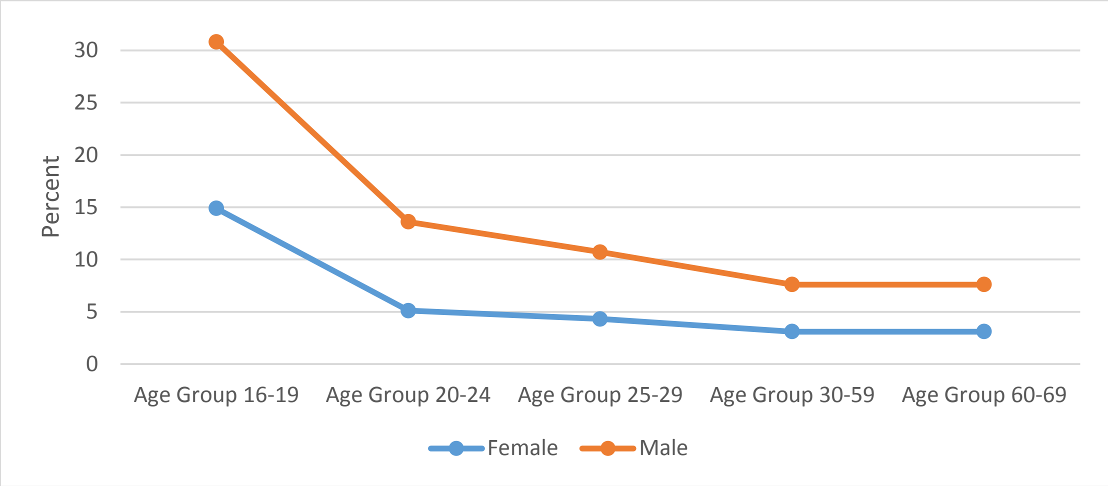


Figure 5: Death in Passenger Vehicle per 100,000 People By Age And Gender 2013

Horrey et al. (2008) researched the gender effect on driving performance (i.e. lane keeping task, stopping task), and they found that gender did not play any role in driving performance when presented with distractions. Stutts et al. (2001) found that the effects of driving while distracted were almost the same in both males and females, although males were slightly more likely than females to be categorized as distracted at the time of their crash.

Horberry et al. (2006) researched the effects of age, road environment complexity, and in-vehicle task in a simulator study. Older people drove at lower speeds compared with younger people in complex highway environments as illustrated in *Figure 6*. Also, distraction was found to have the greatest negative impact on performance of drivers under 25 years old. Wheatley (2002) also saw worse lane keeping and steering wheel control on a curved track compared to a straight track.

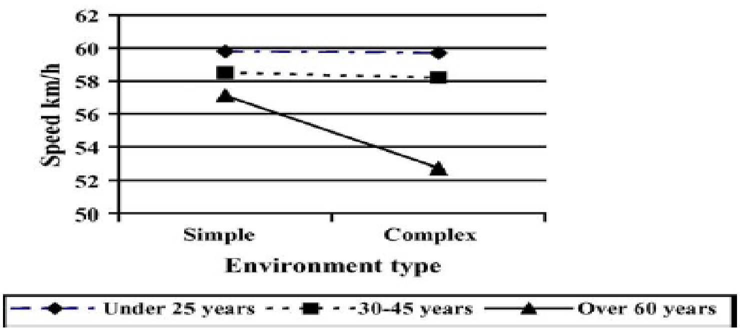


Figure 6: Mean Speed: Environment Type By Age (Horberry et al., 2006)

Assessment and Elimination of Distractions' Effect on Driving Performance

Distractions are ranked using accident reports (Stutts et al., 2001; Stevens & Minton, 2001), laboratory simulation (Consiglio, Driscoll, Witte, & Berg, 2003) and questionnaires and interviews (Patel et al., 2008). According to Kircher (2007), other comprehensive driving-distraction assessment methods include the following:

- Driving simulation
- Questionnaires
- Accident analysis
- Polls
- Field studies
- Test track

Opinion-based surveys tend to rank distractions involving other passengers' conversation as less important than do more technical studies (Patel et al., 2008). Research needs to address this important discrepancy as these conclusions can affect risk-taking behavior. This discrepancy can also influence regulatory actions and make them non-optimal (Patel et al., 2008). Another influence is helping with the development of advanced in-vehicle automation aimed at mitigating distraction (Donmez, Boyle, & Lee, 2007). According to Horrey et al. (2008), the following approaches diminish or eliminate distraction:

- Technology-based intervention could be aimed at mitigating distraction (technology approach).
- Understanding how drivers perceive or misperceive distraction may also help inform application of advanced in-vehicle automation aimed at mitigating distraction. (Horrey et al., 2008).
- Legislative approaches tend to rely on the presence and magnitude of a given form of distraction to eliminate the source of distraction (driver approach).
- Drivers should be educated/trained in the potential risk of in-presence distractions. In Ginsburg et al. (2008), teens with involved parents were less likely to use their cellphone while driving. Mayhew, Simpson, and Pak (2003) showed that the monthly crash rate for beginner learners is low due to being under supervision and that novice crashes are high in the first months and drop dramatically as the drivers acquire more experience, as illustrated in *Figure 7*.

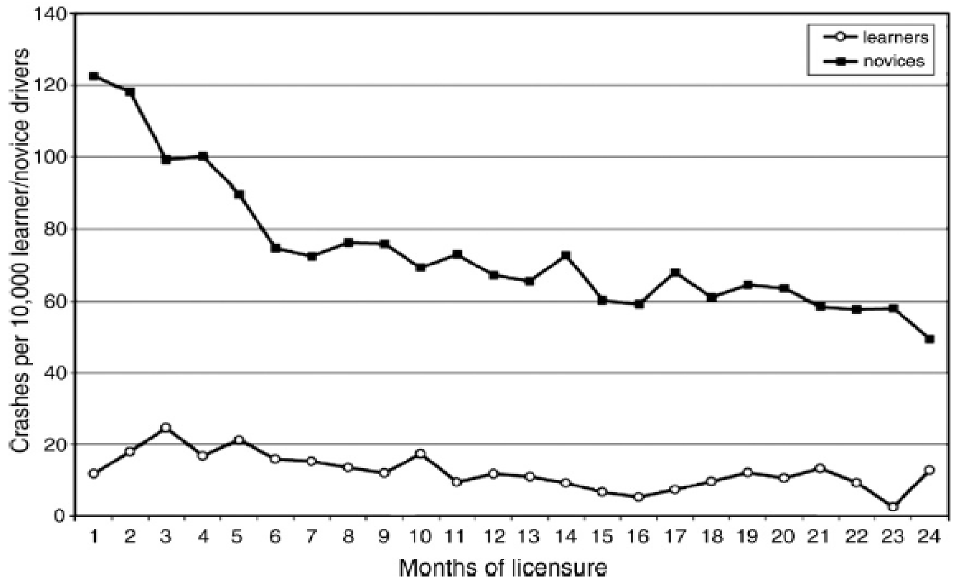


Figure 7: Change In Collision Rate Among Novice Drivers (Mayhew, 2003)

Kircher (2007) also examined the influence of looking away and distractions on performance measurements like speed, lane keeping, and other behavior variables. Each distraction has a unique effect on drivers. For example, teenage drivers tend to apply brakes harder when cognitively distracted. This hard braking can lead to higher changes in speed when compared before and after the presence of the distraction. Lane position change, speeding, and following distance were also screened in the research.

Closest Studies to This Research

This research was similar to that of Consiglio et al. (2003); Strayer and Drews (2004); David L. Strayer and Ward (2013); Horberry et al. (2006); and Kaber, Liang, Zhang, Rogers, and Gangakhedkar (2012) in using a simulator for assessing distraction effects. However, the research that considered similar distractions and road conditions was the NHTSA (2010). This accident analysis found conversation with passenger to be the most important distraction present in crashes and phone use to be the next most important factor. This research also found that the effect of distractions was enhanced by environmentally related factors. The research of Stutts and Association (2001), which is based on police crash reports, found that adjusting a radio in the car is the most dangerous internal distraction.

Positioning of this Study in Cited Literature

Previous research on driving distractions has mainly focused on a single factor rather than researching multiple factors simultaneously. *Table 3* provides a comprehensive list of similar research studies along with the parameters used in each review. This research is unique because it considered the effect of three factors (i.e. gender, distraction, and road condition) for a specific age group (16-18), and it included 11 levels for the distraction factor.

Also this research considered more response variables than most other research and considered ranking of distractions for finding the top five most dangerous distractions. Therefore, the number of response variables and inputs as well as the age group makes this study unique.

Table 3: Literature Review

Authors	Title	Publication/Organization (issue, year)	Setting	Tasks	Measured performances
David L. Strayer and Frak A. Drew	Profiles in Driver Distraction: Effects of Cell Phone Conversations on Younger and Older Drivers	The Journal of the Human Factors and Ergonomics Society 46: 640,2004	Simulator	Wireless phone conversation	Following distance and speed, braking response, brake onset time
Tim Horberry, Janet Anderson, Michael A. Regan, Thomas J. Triggs, John Brown	Driver distraction- the effects of concurrent in-vehicle tasks road environment complexity and age of driving performance	Accident Research Centre, Monash University, Australia National Roads and Motorists' Association, Australia,2006	Simulator	Operating the vehicle entertainment system and conducting a simulated hands-free mobile phone conversation in simple and complex road environments	Drivers perceived workload, Speed related variables: mean speed and deviation from posted speed limit
David B. Kaber , Yulan Liang, Yu Zhang, Meghan L. Rogers, Shruti Gangakhedkar	Driver performance effects of simultaneous visual and cognitive distraction and adaptation behavior	Edward P. Fitts Department of Industrial & Systems Engineering, North Carolina State University, Raleigh, NC Liberty Mutual Institute for Safety, 71 Frankland Road, Hopkinton, 2012	Simulator	Focus on cognitive and visual distractions with eye tracker	Minimum headway distance to the lead vehicle, reaction time to lead vehicle position and speed changes, task completion time

Table 3: Continued

Authors	Title	Publication/Organization ,issue, year	Setting	Tasks	Measured performances
David L. Strayer, Joel M. Cooper, Jonna Turrill, James Coleman, Nate Medeiros-Ward, and Francesco Biondi (University of Utah)	Measuring cognitive Distraction in the Automobile	AAA foundation ,June 2013	Simulator	1) Concurrent listening to a radio, 2) concurrent listening to a book on tape,3) concurrent conversation with a passenger seated next to the participant, 4) concurrent conversation on a hand-held cell phone,5)concurrent conversation on a hands-free cell phone,6) concurrent interaction with a speech-to-text interfaced e-mail system, and 7)concurrent performance with an auditory version of the Operation Span (OSPAN) task	Reaction time and accuracy in response to a peripheral light- detection task, subjective workload measures from the NASA Task Load Index, and physiological Measures associated with electroencephalographic (EEG) activity and Event-Related Brain Potentials (ERPs) time-locked to the peripheral light- detection task.
Santokh Singh, Ph.D.	Distracted Driving and Driver, Roadway, and Environmental Factors	National Highway Traffic Safety Administration ,September 2010	Accident analysis	Looking at movement/actions of other occupants, Dialing/hanging up phone, Adjusting radio/CD player, Adjusting other vehicle controls, Retrieving object from floor and/or seats and all the internal distractions	Accident analysis

Table 3: Continued

Authors	Title	Publication/Organization ,issue, year	Setting	Tasks	Measured performances
William J. Horrey ∗, Mary F. Lesch, Angela Garabet	Assessing the awareness of performance decrements in distracted drivers	Liberty Mutual Research Institute for Safety, September 2008	Test –track	hand-held, hands-free	Variability in lane keeping, accuracy on the pace clock task, brake response time to the changing traffic light, and stop light errors.
Elizabeth Jane Westlake , Linda Ng Boyle	Perceptions of driver distraction among teenage drivers	The University of Iowa, University of Washington, Seattle,2012	Survey	1893 teenager frequency of engagement in distractions included dialing and talking on cellphone, text message, eating and drinking, using iPod or laptop, daydreaming, and thinking about something difficult, etc.	Using clustering to see relationship between age, gender, crash and engagement in distractions
Bruce Simons-Morton , Neil Lerner , Jeremiah Singer	The observed effects of teenage passengers on the risky driving behavior of teenage drivers	Prevention Research Branch, Division of Epidemiology, Statistics, and prevention Research, National Institute of Child Health and Human Development, National Institutes of Health	Field study	Passenger presence in the teenage drivers	Speed and headway distance as a function of driver and passenger characteristic by LIDAR

Chapter 3
Materials and Methods

Basic Setup

This experiment was conducted at the University of Tennessee, Knoxville. Teenage drivers from local high schools volunteered to participate in this research. Each participant drove in a car simulator under various road conditions and with different distractions. Data was gathered and analyzed based on their driving behavior. Simulator setup details and participants' information are presented below in addition to descriptions of the types of distractions, road conditions, and events used in the experiment.

Car Simulator. The RS-600 model car simulator was a full-width Ford Focus with 3 LCD rear-view mirrors and 5 projectors for a 300-degree wraparound display as illustrated in *Figure 8*. The system recorded driving performance data (including driving speed, distance from nearby vehicle, and vehicle lane position) at 60 Hz rate in real-time. The environment was controlled, and all participants were subjected to the same conditions. The advantages of a simulation are that the environment can be controlled and drivers can be subjected to exactly the same situations such as light conditions, road conditions, and weather. Moreover, dangerous situations can be studied without risk of injury or death (Kircher, 2007).

Figure 8: Car Simulation Lab at the University of Tennessee

Participants. Twenty-two participants (12 male, 10 female) ages 16-18 participated in this study. The mean of driving experience was 18 months with a standard deviation of 8.1 as illustrated in *Table 4*. All participants had driver licenses. Additionally, they were all paid $15 USD for participation.

Table 4: Drivers' Gender and Experience

Driver Name	1A	1B	2A	2B	3A	3B	4A
Gender	M	M	F	F	M	M	M
Experience (month)	36	12	18	13	36	12	24
Driver Name	4B	5A	6A	6B	7A	7B	8A
Gender	M	F	M	M	F	F	M
Experience (month)	24	17	24	18	12	12	16
Driver Name	8B	9A	9B	10A	10B	11A	11B
Gender	F	F	F	F	M	F	M
Experience month)	12	24	15	24	1	19	15

Distractions. Eleven levels of distractions were implemented to measure their impact on the response variables, thus determining which distractions are most dangerous. The following distractions and prompts were used in this experiment:

1. Plugging cellphone to charge and pulling up Facebook. Plug in the phone charger, attach the phone to the charger, pull up your Facebook App, and read out loud the first timeline entry on your Facebook home page.

2. Answering/talking/hanging up a call. The following conversation is an example of the type of distraction described as answering/talking/hanging up a call:

"Good morning/afternoon. I am calling to speak with Mr./Ms.______________. I am calling from the Education Charity Trust. I am conducting a survey on behalf of the University of Tennessee regarding the skills young people need to be successful in employment and lifelong learning. It will take about one to two minutes. I would like to have your views on a few of the following topics:

- Mental mathematical skills: the ability to manipulate numbers in head
- Estimation skills: the ability to do an approximate calculation
- Respectful contact within intercultural teams

Thank you for your time. I greatly appreciate your participation. Good-bye."

3. Changing a radio station. Turn radio on and tune to station 102.5.

4. Texting. Type, "I love the University of Tennessee" in your cellphone.

5. Grooming. Pick-up the antibacterial liquid from the bag on the passenger seat; apply some on your hands.

6. Adjusting dashboard controls. Press these keys: A-C-D-B-C-A-D-C-A-D-B-A-D-D-B, two red buttons on the steering wheel.

7. Using GPS. Turn on the navigation device, complete the initial setup if required, and navigate to the nearest Dunkin Donut store.

8. Eating and drinking. Open the bag of chips in one of the bags on the passenger seat, and continue eating or drinking water, or any soft drink.

9. Verbal conversation to passenger. Today's news script – "Hey! Did you hear that…?" "What are your thoughts on this?"

10. Dialing/talking/hanging-up. "Hello, how are you doing? I am doing great. Where are you right now? OH!! That sounds interesting. How did you find out about this study? What time do you expect to get done with the study? Can we discuss more about it after you are done? Ok. See you then. Bye"

11. Cell phone touch screen (Pandora). Turn the phone on, plug in the auxiliary cord, and select a song from the Pandora station.

The activities described above are listed in *Table 5* and categorized according to their type of distraction.

Table 5: Distraction Categories

Distractions	Cognitive	Visual	Biomechanical	Auditory
Verbal conversation to passenger	C	V		A
Dialing/talking/hanging-up	C	V	B	A
Changing a radio station	C	V	B	
Texting	C	V	B	
Adjusting dashboard controls	C	V	B	
Answering/talking/hanging up a call	C		B	A
Plugging cellphone to charge and pulling up Facebook		V	B	
Using GPS		V	B	
Cell phone touch screen (Pandora)		V	B	
Grooming			B	
Eating and drinking			B	

Road Conditions. Different road conditions were used to measure their impact on the response variables and to determine which were causing the worst driving behavior. *Table 6* identifies the road conditions used in this experiment.

Table 6: Road Conditions

Road Condition	Speed limit (mph)	Road type	Traffic	Weather	Curvy	Difficulty
Road Segment 1	55	Highway	Average	Clear	Slightly curvy	Moderate
		Easy	Moderate	Easy	Moderate	
Road Segment 2	25	Residential	Average	Clear	Straight	Moderate
		Moderate	Moderate	Easy	Easy	
Road Segment 3	25	Urban	Average	Rainy	Straight	Moderate
		Easy	Moderate	Moderate	Easy	
Road Segment 4	25	Urban	Average	Clear	Straight	Moderate
		Easy	Moderate	Easy	Easy	
Road Segment 5	25	Rural	High	Snowy	Curvy	Difficult
		Difficult	Difficult	Difficult	Difficult	

Events. Different events were also used to measure their impact on the response variables. The following events happened in Road Segments 1, 2 and 4, respectively, and they occurred after the distractions.

- Dog: A dog suddenly jumped in front of the car on a highway.
- Kids: Kids were passing the road in a residential area.
- Ambulance: An ambulance suddenly came in front of the car in a city.

Experiment Set-Up

The experiment was set up using a Balanced Incomplete Block Design, as shown in *Table 7*. This design allowed for five different road segments with various, randomized distractions. Once the experiment was designed, the factors were entered in the car simulator.

Table 7: Balanced Incomplete Block Design

Participant	Road Segment 1	Road Segment 2	Road Segment 3	Road Segment 4	Road Segment 5
1A	GPS	Charging ,read out Facebook	Eating/Drinking	Radio	Adjusting dashboard controls
2A	Cell Phone touch screen (Pandora)	GPS	Driver Initiated Conversation	Dialing/Talking/ Hanging up	Eating/Drinking
3A	Answering/Talking/ Hanging up	Grooming	GPS	Driver Initiated Conversation	Charging ,read out Facebook
4A	Cell Phone Texting	Answering/ Talking/ Hanging up	Cell Phone touch screen (Pandora)	GPS	Radio
5A	Dialing/Talking/ Hanging up	Cell Phone Texting	Adjusting dashboard controls	Grooming	GPS
6A	Grooming	Cell Phone touch screen (Pandora)	Charging, read out Facebook	Eating/Drinking	Cell Phone Texting
7A	Charging ,read out Facebook	Driver Initiated Conversation	Radio	Cell Phone Texting	Dialing/Talking/ Hanging up
8A	Driver Initiated Conversation	Eating/Drinking	Cell Phone Texting	Adjusting dashboard controls	Answering/ Talking/ Hanging up
9A	Eating/Drinking	Radio	Dialing/Talking/ Hanging up	Answering/Talking /Hanging up	Grooming
10A	Adjusting dashboard controls	Dialing/Talking/ Hanging up	Answering/Talkin g/Hanging up	Charging ,read out Facebook	Cell Phone touch screen (Pandora)
11A	Radio	Adjusting dashboard controls	Grooming	Cell Phone touch screen (Pandora)	Driver Initiated Conversation
	Road Segment 1	Road Segment 2	Road Segment 3	Road Segment 4	Road Segment 5
1B	Driver Initiated Conversation	GPS	Dialing/Talking/ Hanging up	Answering/Talking /Hanging up	Eating/Drinking
2B	Cell Phone Texting	Driver Initiated Conversation	Cell Phone touch screen (Pandora)	Radio	Dialing/Talking/ Hanging up
3B	Adjusting dashboard controls	Charging ,read out Facebook	Driver Initiated Conversation	Cell Phone touch screen (Pandora)	GPS
4B	Grooming	Adjusting dashboard controls	Cell Phone Texting	Driver-initiated Conversation	Answering/ Talking/ Hanging up
5B	Radio	Grooming	Eating/Drinking	Charging, read out Facebook	Driver Initiated Conversation
6B	Charging ,read out Facebook	Cell Phone Texting	GPS	Dialing/Talking/ Hanging up	Grooming
7B	GPS	Cell Phone touch screen (Pandora)	Answering/Talkin g/Hanging up	Grooming	Radio
8B	Cell Phone touch screen (Pandora)	Dialing/Talking/ Hanging up	Grooming	Eating/Drinking	Adjusting dashboard controls
9B	Dialing/Talking/ Hanging up	Answering/ Talking/ Hanging up	Radio	Adjusting dashboard controls	Charging, read out Facebook
10B	Eating/Drinking	Radio	Adjusting dashboard controls	GPS	Cell Phone Texting
11B	Answering/Talking/ Hanging up	Eating/Drinking	Charging, read out Facebook	Cell Phone Texting	Cell Phone touch screen (Pandora)

Conduct Experiment

After setting up the experiment as mentioned above, it was conducted according to a specific procedure and in a controlled environment. In the following sections, the details of the experimental procedures and environment are described.

Experimental Procedures. All teenage drivers provided a consent form signed by both parents/guardians and the participant. The participants were familiarized with the function of the devices they would use during driving. They were instructed to obey standard traffic rules, to follow any action displayed on the screen, and not to exceed the speed limit. They were advised to drive in a manner to avoid collision with pedestrians or other vehicles.

Environment. The participants were familiarized with the car and simulation in a warm-up driving exercise that lasted nearly 15 minutes. One issue with the simulator was that it caused dizziness and nausea. If the participants did not feel dizzy upon completing the warm-up exercise, they continued participating on the experimental road, pictured in *Figure 9*. If they felt dizzy, they did not continue the experiment.

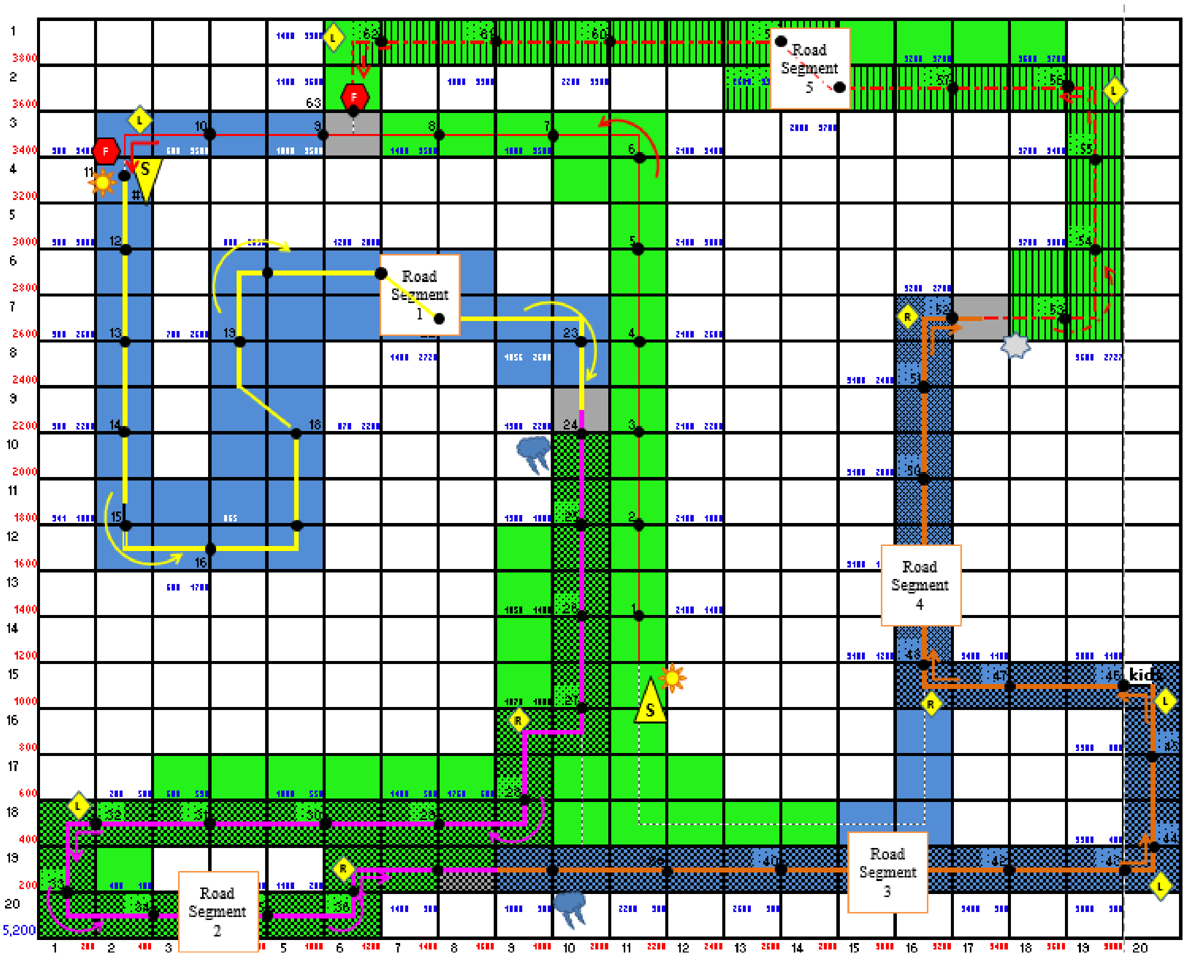


Figure 9: The Path Each Driver Drives

Database

During the experiment, data from the car-simulation equipment was collected for each driver and stored in individual driver excel sheets. For each driver, about 31,000 rows and 40 columns of information were collected as shown in *Table 8*. The database contains 656,816 rows and about 40 columns (variables).

Table 8: Sample of Collected Variables in Car Simulation

Acceleration	Brake	Headway Distance	Collision
Lane Count	Lane Position	Signal	Culture Type
Slip	Speed Limit	Subject Engine RPM	Active Trigger
Subject X	Subject Y	Subject Z	Lane Name
Vehicle Ahead	Terrain Type	Steer	Velocity

Data Preparation for Analysis

Data for each driver was analyzed under three separate conditions. First, data was gathered while the participant was driving without exposure to distractions or events (i.e., “No Distraction”). Next, data was gathered while the participant was driving in the presence of a distraction (i.e., “Only Distraction). Finally, data was gathered while the participant was driving in the presence of both a distraction and an event (i.e., “Event and Distraction”). Three different road divisions were used for these varying conditions as illustrated in *Figure 10*.

No Distraction	Only Distraction	Event and Distraction

Figure 10: Road Divisions

“No Distraction” Location. The “No Distraction” location was based on the same conditions as the “Only Distraction” location but with no distractions occurring.

“Only Distraction” Location. When the participant began driving in the presence of a distraction, the distraction’s starting location was saved by the car simulator and was based on X, Y, shown below in *Table 9* and above in *Figure 9*.

Table 9: "Only Distraction" Location

	X	Y
starting location of distraction for “Road Segment 1”	1045.092	2892.802
starting location of distraction for “Road Segment 2”	769.6	98.2
starting location of distraction for “Road Segment 3“	2937.8	296.2
starting location of distraction for “Road Segment 4”	3106.9	1243.3
starting location of distraction for “Road Segment 5”	2644.7	3892.9

Unfortunately, because each distraction that occurred was specified, data had to be entered manually.

"Event and Distraction" Location. Data from the car simulator, labeled as "Vehicle Ahead," shows each event variable that drivers encountered in the "Event and Distraction" location. For example, *Table 10* shows data gathered from the event of a dog crossing the street.

Table 10: Event Location

Source Table	Velocity	Lane Position	Acceleration	Brake	Speed Limit	Vehicle Ahead
11BMS	7.773	-0.05	0.229	0	20	Dog
11BMS	7.863	-0.05	0.226	0	20	Dog
11BMS	7.951	-0.05	0.225	0	20	Dog
11BMS	8.035	-0.05	0.224	0	20	Dog
11BMS	8.118	-0.05	0.219	0	20	Dog
11BMS	8.198	-0.051	0.216	0	20	Dog
11BMS	8.275	-0.051	0.214	0	20	-
11BMS	8.348	-0.052	0.212	0	20	-

Response Variables

This experiment relied on manipulating certain independent variables (i.e., road conditions, gender, and distraction) to determine changes in the dependent variables (i.e., velocity, lane position, and headway distance). For example, Drews (2004); Fairclough, May, and Carter (1997); Greenberg et al. (2003); Kaber et al. (2012); and Simons-Morton, Lerner, and Singer (2005) considered headway distance in their analyses. Horberry et al. (2006), Simons-Morton et al. (2005), and Drews (2004) used mean speed. Kaber et al. (2012) used speed variability. Greenberg et al. (2003) and Horrey et al. (2008) used variability in lane position.

Chapter 4

Results and Discussion

Factors that Affect Teenage Driving Performance

This experiment sought to identify which factors based on gender, distraction, and road conditions have statistically significant effects on teenage driving performance. The regression model describes variation in response variables, or teenage driving performance variables, including SD velocity, SD lane position, and mean velocity. The model contains inputs such as gender, distraction, and road conditions recorded in 110 observations, as shown in *Table 11*. For these observations, the driver was put in the model as a random variable. Each driver had five observations, which were not independent of each other. Therefore, analyses with 110 observations were mixed model. The model's purpose was to identify statistically significant factors based on gender, distraction, and road condition in the road segment where "only distractions" were happening. This segment of the simulation occurred before events and distraction, as presented in *Figure 11*.

If standard deviation is in the response, the transformation of Log (SD) is usually used in regression. The analyses revealed the road condition factor was statistically significant in all the response variables.

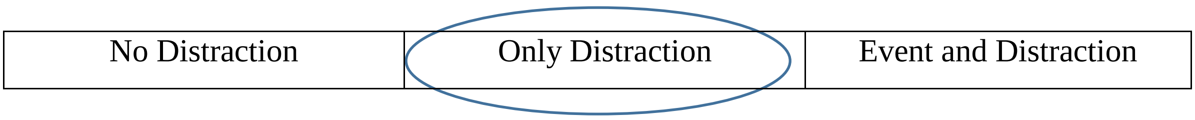


Figure 11: Road Divisions of "Only Distraction"

Table 11: Balanced Incomplete Block Design with Road Condition, Distraction and Gender Factors

	Road Segment 1	Road Segment 2	Road Segment 3	Road Segment 4	Road Segment 5		Road Segment 1	Road Segment 2	Road Segment 3	Road Segment 4	Road Segmen t 5
1A	1	2	3	4	5	1B	7	1	8	9	3
2A	6	1	7	8	3	2B	11	7	6	4	8
3A	9	10	1	7	2	3B	5	2	7	6	1
4A	11	9	6	1	4	4B	10	5	11	7	9
5A	8	11	5	10	1	5B	4	10	3	2	7
6A	10	6	2	3	11	6B	2	11	1	8	10
7A	2	7	4	11	8	7B	1	6	9	10	4
8A	7	3	11	5	9	8B	6	8	10	3	5
9A	3	4	8	9	10	9B	8	9	4	5	2
10A	5	8	9	2	6	10B	3	4	5	1	11
11A	4	5	10	6	7	11B	9	3	2	11	7

Factors that Affect Log SD Velocity. This model was used to determine which factors based on gender, distraction, and road conditions ocurring in the "Only Distraction" location have statisticaly significant effects on log SD velocity. Based on the effect tests described in *Figure 12*, out of the three inputs, road condition was the only significant factor (P-value <0.0001). The other two factors, distraction and gender, were not considered significant.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Gender	1	1	21.26	0.3901	0.5389
Distraction	10	10	81.35	0.7245	0.6992
Road Condition	4	4	74.48	18.3680	<.0001*

Figure 12: Effect Tests of Y= Log (SD Velocity of "Only Distraction") X= Distraction, Road Condition, and Gender

According to the gender plot illustrated in *Figure 13*, male and female drivers were almost the same. However, numerically speaking, male drivers had higher speed variation in the presence of distractions. In addition to analyzing gender, distraction, and road condition factors, different levels of road conditions were analyzed to determine which levels had a higher effect on log SD velocity.

Least Squares Means Table

Level	Least Sq Mean	Std Error
F	-0.6677551	0.14978452
M	-0.5398452	0.13646316

LS Means Plot

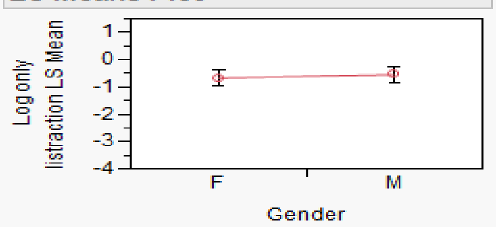


Figure 13: Gender Plot of Y= Log (SD Velocity of "Only Distraction") X= Distraction, Road

Road condition factors that affect log SD velocity. Different road conditions are compared in this model to determine which level of road condition factors have a higher effect on log SD velocity. "Road Segment 5" was in a rural area with heavy traffic, and it had the highest rank. It was in Group A while "Road Segment 4" and "Road Segment 2" were in Group B and "Road Segment 1" and "Road Segment 3"were in Group C. "Road Segment 5" had the most velocity change as shown in *Figure 14*.

Level		Least Sq Mean
Road Segement 5	A	1.3980708
Road Segement 4	B	0.6970842
Road Segement 2	B C	0.4399621
Road Segement 3	C	0.3750301
Road Segement 1	C	0.3037867

Levels not connected by same letter are significantly different.

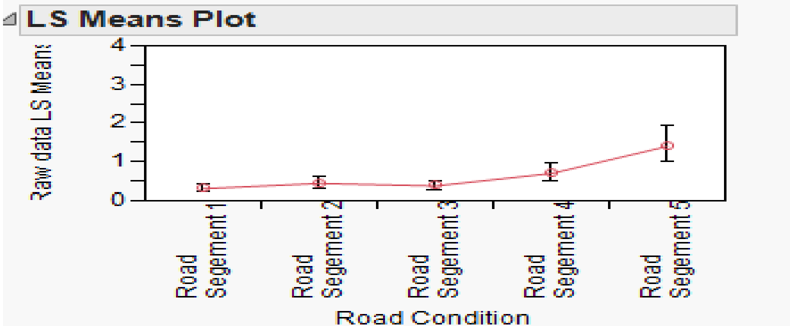


Figure 14: Road Condition Plot of Y= Log (SD Velocity of "Only Distraction"), X= Distraction, Road Condition, and Gender

Factors that Affect Mean Velocity. Below is the model that was used to determine which factors based on gender, distraction, and road conditions occurring in the "Only Distraction" location have statistically significant effects on mean velocity. According to *Figure 15*, road condition is considered important.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Gender	1	1	20.34	2.6637	0.1180
Distraction	10	10	84.96	0.3400	0.9675
Road Condition	4	4	73.05	165.9307	<.0001*

Summary of Fit

RSquare	0.885857
RSquare Adj	0.867643
Root Mean Square Error	1.773035
Mean of Response	14.70348
Observations (or Sum Wgts)	110

Figure 15: Fit Summary and Effect Tests of Y= Mean Velocity of "Only Distraction" Location, X= Distraction, Road Condition, Gender

In these results, gender was not found to be statistically significant (P-value 0.11), as shown in *Figure 15*. However, numerically speaking, males drove faster than females, as illustrated in *Figure 16*. In addition to analyzing gender, distraction, and road condition factors, different levels of road conditions were analyzed to determine which levels had a higher effect on mean velocity.

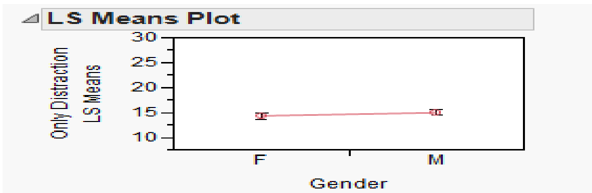


Figure 16: Gender Plot of Effect Tests of Y= Mean Velocity of "Only Distraction" Location, X= Distraction, Road Condition, Gender

Road condition factors that affect mean velocity. In this model different road conditions are compared to determine which level of road conditions has a higher effect on mean velocity. Mean velocity for the road condition was grouped into three categories: Road Segment 1 was categorized in Group A; Road Segment 4, Road Segment 5, and Road Segment 3 in Group B; and Road Segment 2 in Group C, as illustrated in *Figure 17*.

Level			Least Sq Mean
Road Segement 1	A		23.290811
Road Segement 4	B		13.526085
Road Segement 5	B	C	12.562441
Road Segement 3	B	C	12.449095
Road Segement 2		C	11.533053

Levels not connected by same letter are significantly different.

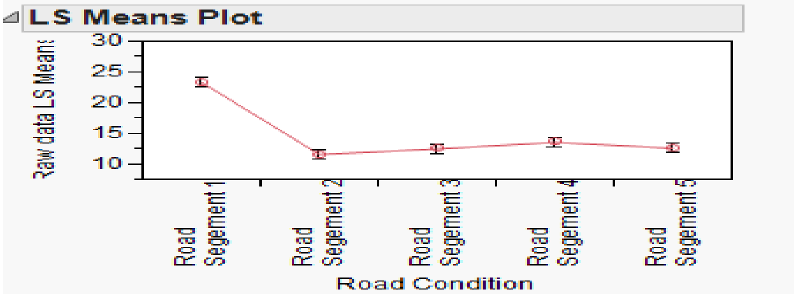


Figure 17: Road Condition Plot of Y= Mean Velocity of "Only Distraction" Location, X= Distraction, Road Condition and Gender

Factors that Affect Log SD Lane Position. This model was used to determine which factors based on gender, distraction, and road conditions ocurring in the "Only Distraction" location have statisticaly significant effects on log SD lane position. *Figure 18* shows that road condition was the only significant factor among the three factors (P-value <0.0001).

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Distraction	10	10	82.29	0.6490	0.7676
Gender	1	1	20.34	0.7332	0.4018
Road Condition	4	4	73.39	40.8859	<.0001*

Figure 18: Effect Tests of Y= Log SD Lane Position of "Only Distraction" Location, X= Road Condition, Gender, Distraction

Based on the gender plot shown in *Figure 19*, log SD lane position in the "Only Distraction" location is almost the same for both male and female drivers.

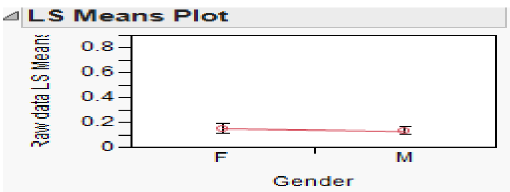


Figure 19: Gender Plot of Y= Log SD Lane Position of "Only Distraction" Location, X= Road Condition, Gender, Distraction

As shown in *Figure 20*, Road Segment 5 and Road Segment 1 had high SD of lane position. In addition to analyzing gender, distraction, and road condition factors, gender × distraction factor was analyzed to determine if it had a statistically significant effect on log SD lane position as described in the following section.

Level					Least Sq Mean
Road Segement 5	A				0.35862442
Road Segement 1	A				0.25782239
Road Segement 4		B			0.14147456
Road Segement 2			C		0.08392613
Road Segement 3				D	0.04706112

Levels not connected by same letter are significantly different.

LS Means Plot

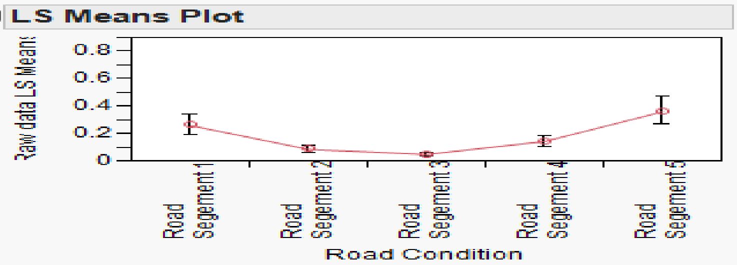


Figure 20: Road Condition Plot of Y: Log SD Lane Position of "Only Distraction" Location, Factor: Road Condition, Gender, Distraction

Gender × distraction factor's effect on log SD lane position. The interaction between gender and distraction is shown in *Figure 21*. The behavior of males versus females for the effect of each distraction on lane position was analyzed. The Parameter Estimates shows that gender × distraction factor is not important. If more data were collected, this interaction might have otherwise been statistically significant.

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	-1.965743	0.087306	19.4	-22.52	<.0001*
Distraction[Adjusting dashboard contols]	-0.131571	0.192052	72.69	-0.69	0.4955
Distraction[Answering/Talking/Hanging up]	-0.282281	0.196065	73.12	-1.44	0.1542
Distraction[Cell Phone Texting]	0.035721	0.209008	73.8	0.17	0.8648
Distraction[Cell Phone touch screen (Pandora)]	0.1018277	0.195832	72.89	0.52	0.6047
Distraction[Charging ,read out Facebook]	0.041887	0.209142	74.02	0.20	0.8418
Distraction[Dialing/Talking/Hanging up]	0.2931107	0.239346	74.71	1.22	0.2246
Distraction[Eating-Drinking]	-0.030207	0.209143	73.75	-0.14	0.8856
Distraction[FM/AM station selection]	0.150596	0.195674	72.82	0.77	0.4440
Distraction[GPS]	0.1310557	0.208455	72.88	0.63	0.5315
Distraction[Grooming]	-0.049223	0.191779	72.53	-0.26	0.7982
Gender[F]	0.0646657	0.087324	19.4	0.74	0.4678
Road Condition[Road Segement 1]	0.6563908	0.122065	64.74	5.38	<.0001*
Road Condition[Road Segement 2]	-0.503236	0.121965	64.93	-4.13	0.0001*
Road Condition[Road Segement 3]	-1.111854	0.124722	65.32	-8.91	<.0001*
Road Condition[Road Segement 4]	-0.006506	0.120736	64.58	-0.05	0.9572
Distraction[Adjusting dashboard contols]*Gender[F]	0.1933845	0.192084	72.72	1.01	0.3174
Distraction[Answering/Talking/Hanging up]*Gender[F]	-0.136148	0.203718	73.72	-0.67	0.5060
Distraction[Cell Phone Texting]*Gender[F]	0.2530698	0.211717	73.92	1.20	0.2358
Distraction[Cell Phone touch screen (Pandora)]*Gender[F]	-0.289865	0.197404	72.94	-1.47	0.1463
Distraction[Charging ,read out Facebook]*Gender[F]	-0.023709	0.211978	74.11	-0.11	0.9112
Distraction[Dialing/Talking/Hanging up]*Gender[F]	-0.163987	0.242771	74.97	-0.68	0.5015
Distraction[Eating-Drinking]*Gender[F]	-0.233775	0.212001	73.87	-1.10	0.2737
Distraction[FM/AM station selection]*Gender[F]	0.1836539	0.198074	73.08	0.93	0.3569
Distraction[GPS]*Gender[F]	0.0210766	0.21132	73.24	0.10	0.9208
Distraction[Grooming]*Gender[F]	0.196786	0.202246	73.45	0.97	0.3337

Figure 21: Parameter Estimates of Y= Log SD Lane Position "Only Distraction" Location, X= Road Condition, Gender, Distraction, Gender × Distraction

In *Figure 22*, SD lane position of the “Only Distraction” location for male and female drivers is shown. These distractions have led to variation in male and female drivers’ behavior, with distractions affecting male drivers more. If more data were gathered and the slope for *Figure 22* was positive for all the distractions, this interaction would have been statistically significant. In this experiment, the amount of data was not enough to reach any further conclusions about gender and distractions.

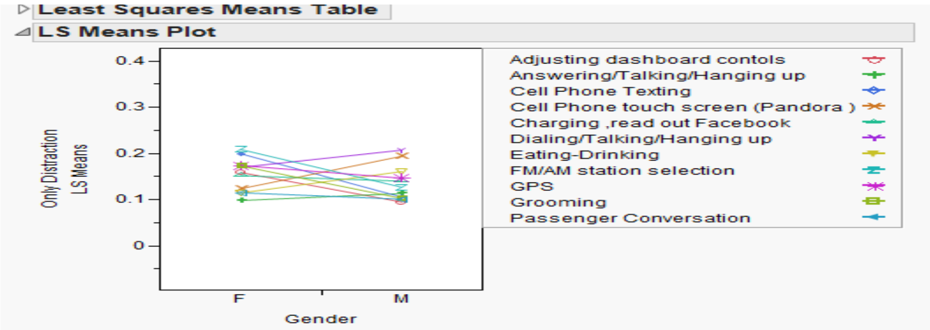


Figure 22: Distraction×Gender Plot of Y= Log SD Lane Position “Only Distraction” Location, X= Road Condition, Gender, Distraction, Gender × Distraction

Checking the Need for a “No Distraction” Area as a Baseline in the Model

To assess whether or not to use a “No Distraction” location in the model as a baseline, some analyses were done by checking correlation, coefficient, and R square values in the presence/absence of this factor in the model.

Variable SD Velocity of “No Distraction” Location. To assess whether to use a “No Distraction” location in the SD velocity model as a baseline, correlation and coefficient values in the presence/absence of SD velocity of “No Distraction” location was checked. First the correlation between log (SD velocity of “No Distraction”) and log (SD velocity of “Only Distraction”) is shown in *Figure 23*.

Correlations

	Log no distraction	Log only distraction
Log no distraction	1.0000	0.4999
Log only distraction	0.4999	1.0000

Partial Corr

	Log no distraction	Log only distraction
Log no distraction	.	0.4999
Log only distraction	0.4999	.

partialed with respect to all other variables

Figure 23: Correlation with and without Assumption of Normality

As shown in *Figure 24*, the slope is statistically important, possibly meaning that using SD velocity of “No Distraction” may be helpful for the model. However, ellipses in

Figure 24 describe the reason for this positive correlation. The road condition is the hidden factor for this misleading correlation.

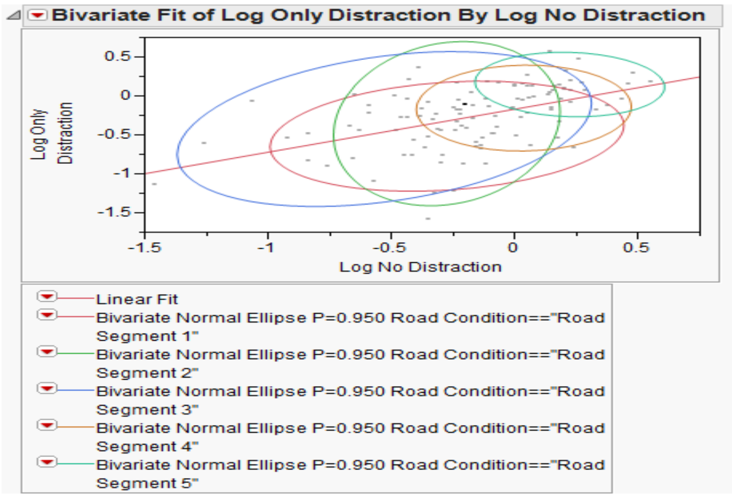


Figure 24: Correlation of SD Velocity Only Distraction and SD Velocity No Distraction

To determine in another way whether SD velocity of "No Distraction" was needed as a baseline in the computations, log (SD velocity of "No Distraction") was put as an input in the model. The coefficient's size for log (SD velocity of "No Distraction") in the model provides the size of that variable's effect on log (SD velocity of "Only Distraction"). In other words, to check the importance of using the "No Distraction" location as baseline, the coefficient of log (SD velocity of "No Distraction") should have a value of at least 0.5. Because the slope for log SD (velocity of "No Distraction") in *Figure 25* is 0.07, the SD velocity of "No Distraction" was not an important factor.

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	-0.249352	0.04821	26.13	-5.17	<.0001*
Log No Distraction	0.0765788	0.136976	91.02	0.56	0.5775
Distraction[Adjusting dashboard contols]	0.0409485	0.091949	80.01	0.45	0.6573
Distraction[Answering/Talking/Hanging up]	-0.060601	0.092045	79.98	-0.66	0.5122
Distraction[Cell Phone Texting]	0.0170533	0.092908	79.9	0.18	0.8548
Distraction[Cell Phone touch screen (Pandora)]	-0.054969	0.093051	80.64	-0.59	0.5563
Distraction[Charging ,read out Facebook]	0.071707	0.092163	79.04	0.78	0.4389
Distraction[Dialing/Talking/Hanging up]	0.1576941	0.092737	76.74	1.70	0.0931
Distraction[Eating-Drinking]	0.0503802	0.092111	79.27	0.55	0.5859
Distraction[FM/AM station selection]	0.0196525	0.092206	79.57	0.21	0.8318
Distraction[GPS]	-0.051013	0.093244	81.04	-0.55	0.5858
Distraction[Grooming]	-0.085251	0.091969	80	-0.93	0.3567
Gender[F]	-0.025351	0.043566	19.23	-0.58	0.5674
Road Condition[Road Segment 1]	-0.246706	0.057741	72.99	-4.27	<.0001*
Road Condition[Road Segment 2]	-0.085802	0.057768	73.01	-1.49	0.1418
Road Condition[Road Segment 3]	-0.135786	0.074814	81.55	-1.81	0.0732
Road Condition[Road Segment 4]	0.0901635	0.062102	75.93	1.45	0.1507

Figure 25: Parameter Estimates of Y= Log (SD Velocity of "Only Distraction") X=Distraction, Event, Gender, Log (SD Velocity of "No Distraction")

Variable Mean Velocity of "No Distraction" Location. The "No Distraction" location's mean velocity was checked to see if it was needed in the model as an input; it was not used. Thus, the model was used to identify statistically significant factors.

The need for putting mean velocity of "Only Distraction" minus mean velocity of "No Distraction" as Y was considered. The other option to create the model was to use just the mean velocity of "Only Distraction." The Mean Velocity's R Square of the "Only Distraction" location minus the "No Distraction" location's mean velocity was R^2=0.157, described in *Figure 26*. R Square of the model with "No Distraction" location, R^2=0.157, was lower than R square of the model with the mean velocity of the "Only Distraction" location, R^2=0.88 as shown in *Figure 15* on page 28, and therefore was not used as a baseline. In other words, using mean velocity of the "No Distraction" location did not help to explain more variation in the model, but rather worsened it.

Figure 26: Fit Summary of Y= Mean Velocity Changes (Mean Velocity of "Only Distraction" Location minus Mean Velocity of "No Distraction" location), X: Distraction, Road Condition, and Gender

Variable SD Lane Position of "No Distraction" Location. SD lane position of the "No Distraction" location was checked to see if it was needed in the model as an input; it was not used. Thus, the model was used to identify statistically significant factors.

The correlation between the "Only Distraction" location's SD lane position and the "No Distraction" locations' SD lane position was analyzed. The slope was found to be important due to event differences. This road condition impact is shown in *Figure 27* with each ellipse showing one road condition.

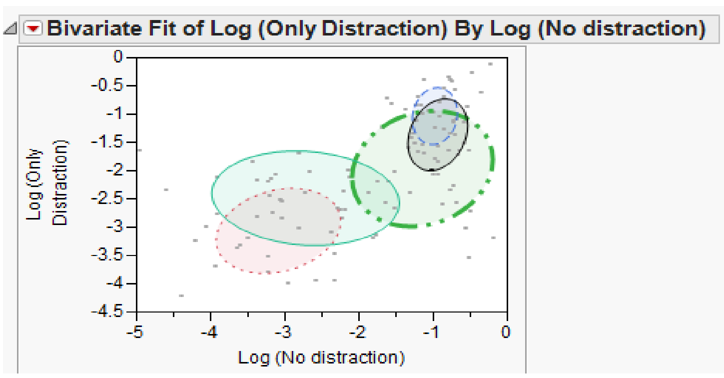


Figure 27: Correlation of SD Lane "Only Distraction" and SD Lane "No Distraction"

The coefficient for log SD lane position of the "No Distraction" location in the *Figure 28* is only 0.0397. Therefore, the "No Distraction" location's SD Lane Position was not an important factor, and the road condition caused the correlation.

Summary of Fit

RSquare	0.703042
RSquare Adj	0.651953
Root Mean Square Error	0.608349
Mean of Response	-1.9806
Observations (or Sum Wgts)	110

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	-1.903138	0.184715	90.09	-10.30	<.0001*
Log(Area without Distraction)	0.0397019	0.093075	86.75	0.43	0.6708
Distraction[Adjusting dashboard contols]	-0.111835	0.190592	81.98	-0.59	0.5590
Distraction[Answering/Talking/Hanging up]	-0.248646	0.190844	81.77	-1.30	0.1963
Distraction[Cell Phone Texting]	-0.062675	0.191458	81.55	-0.33	0.7442
Distraction[Cell Phone touch screen (Pandora)]	0.0498514	0.19161	81.13	0.26	0.7954
Distraction[Charging ,read out Facebook]	0.0476689	0.191189	81.42	0.25	0.8037
Distraction[Dialing/Talking/Hanging up]	0.1912158	0.193259	78.29	0.99	0.3255
Distraction[Eating-Drinking]	0.0915401	0.190969	81.29	0.48	0.6330
Distraction[FM/AM station selection]	0.2029358	0.191721	82.34	1.06	0.2929
Distraction[GPS]	0.1342317	0.191728	80.97	0.70	0.4859
Distraction[Grooming]	-0.038599	0.192677	81.3	-0.20	0.8417
Gender[F]	0.0763059	0.083311	20.54	0.92	0.3703
Road Condition[Road Segment 1]	0.5855803	0.139664	76.92	4.19	<.0001*
Road Condition[Road Segment 2]	-0.466089	0.145708	77.79	-3.20	0.0020*
Road Condition[Road Segment 3]	-1.030014	0.168575	80.24	-6.11	<.0001*
Road Condition[Road Segment 4]	-0.006469	0.129925	75.23	-0.05	0.9604

Figure 28: Fit Summary and Parameter Estimates of Y= Log SD Lane Position of "Only Distraction" Location, X= Road Condition, Gender, Distraction, SD Lane Position of "No Distraction" Location

Factors that Affect Teenage Driving Performance Given Fixed Road Conditions and No Events

Based on results from the previous analysis, road condition was removed from the list of inputs. Because road condition was statistically important in the previous models, removing it helped determine other factors' effects. Additionally, when the various road conditions were compared, more variation was related to distraction and gender factors. As an example, *Table 12* shows Road Segment 1 with 22 observations. These observations were put into the model, and the important factors were found. Other road conditions were analyzed in the same way.

Table 12: Road Segment 1

Location	Road Segment 1	Location	Road Segment 1
1A	GPS	1B	Driver Initiated Conversation
2A	Cell Phone touch screen (Pandora)	2B	Cell Phone Texting
3A	Answering/Talking/Hanging up	3B	Adjusting dashboard controls
4A	Cell Phone Texting	4B	Grooming
5A	Dialing/Talking/Hanging up	5B	Radio
6A	Grooming	6B	Charging ,read out Facebook
7A	Charging ,read out Facebook	7B	GPS
8A	Driver Initiated Conversation	8B	Cell Phone touch screen (Pandora)
9A	Eating/Drinking	9B	Dialing/Talking/Hanging up
10A	Adjusting dashboard controls	10B	Eating/Drinking
11A	Radio	11B	Answering/Talking/Hanging up

"Road Segment 1" Road Condition. Log SD lane position, log SD velocity, and mean velocity were response variables in "Road Segment 1." Twenty-two drivers were analyzed. From the response variables, the mean velocity model found texting to be a dangerous distraction. Additionally, other models for log SD lane position and log SD velocity were shown and discussed.

"Road Segment 1" with no event: factors that affect log SD lane position. Twenty-two observations were used in this model. Based on *Figure 29*, in "Road Segment 1," variable SD lane position did not find any important factors in the regression model.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	1.6615454	0.5228	0.8394
Gender	1	1	0.7592625	2.3889	0.1532

Figure 29: Effect Tests of Y=Log SD Lane Position (Road Segment 1), X=Distractions, Gender

"Road Segment 1" with no event: factors that affect log SD velocity. In this model, regression was used for the 22 observations. SD velocity did not help to find important factors in the model as shown in *Figure 30*. Based on these results, gender and distraction P-values are 0.39 and 0.62, respectively, showing that neither is significant.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	4.9983988	1.1808	0.3989
Gender	1	1	0.1094754	0.2586	0.6221

Figure 30: Effect Tests of Y=Log SD Velocity (Road Segment 1), X=Distractions, Gender

"Road Segment 1" with no event: factors that affect mean velocity. Twenty-two pieces of data were analyzed in this case. *Figure 31* shows the effect tests for "Road Segment 1." Based on these results, gender and distraction P-values are 0.34 and 0.09, respectively, showing that neither is significant. Gender seems to be marginally important because the P-value is 0.09, which is very low, and the F ratio is 3.5. As shown in *Figure 31*, males drove faster than females, which is possibly a reason why males have more accidents according to accident statistics.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	67.185230	1.3004	0.3429
Gender	1	1	18.182154	3.5191	0.0901

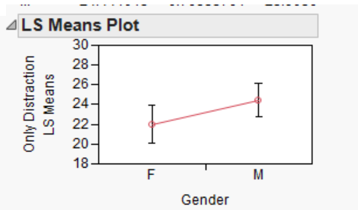


Figure 31: Effect Tests and Gender Plot of Y=Mean Velocity(Road Segment 1), X=Distractions, Gender

Moreover, participants who were texting while driving drove faster, and this higher speed was a statistically significant for texting in comparison with other distractions, as illustrated in *Figure 32* (t ratio= 2.47, P-value =0.03).

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	23.210089	0.48827	47.54	<.0001*
Distraction[Adjusting dashboard contols]	-0.111252	1.533639	-0.07	0.9436
Distraction[Answering/Talking/Hanging up]	-0.498763	1.644482	-0.30	0.7679
Distraction[Cell Phone Texting]	3.790363	1.533639	2.47	0.0330*
Distraction[Cell Phone touch screen (Pandora)]	1.2689306	1.691416	0.75	0.4704
Distraction[Charging ,read out Facebook]	-3.363839	1.533639	-2.19	0.0530
Distraction[Dialing/Talking/Hanging up]	0.8766366	1.691416	0.52	0.6155
Distraction[Eating-Drinking]	0.5955948	1.533639	0.39	0.7059
Distraction[FM/AM station selection]	0.503274	1.533639	0.33	0.7496
Distraction[GPS]	0.7202487	1.533639	0.47	0.6487
Distraction[Grooming]	-2.514983	1.644482	-1.53	0.1572
Gender[F]	-1.230926	0.656168	-1.88	0.0901

Figure 32: Parameter Estimates of Y=Mean Velocity(Road Segment 1), X=Distractions, Gender

"Road Segment 2" Road Condition. Log SD lane position, log SD velocity, and mean velocity in "Road Segment 2" were investigated for 22 pieces of data. The three variables did not show any statistically significant input. Looking at gender, males were numerically worse for SD lane position and mean velocity, but females had higher log SD velocity. However, this difference for gender was not statistically important.

"Road Segment 2" with no event: factors that affect log SD lane position.As shown in *Figure 33,* P-values for distraction and gender were not significant and not found important. Males have more variation in lane position than females. Only the value of variation is numerically higher and is not found to be statistically significant.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	5.1705078	0.9743	0.5160
Gender	1	1	0.2903136	0.5470	0.4765

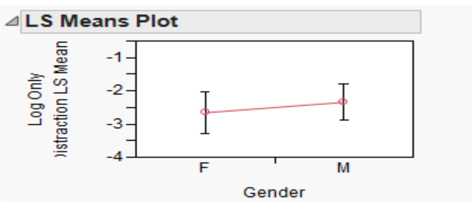


Figure 33: Effect test and Gender Plot of Y=Log SD Lane Position (Road Segment 2), X=Distractions, Gender

On the distraction estimates in *Figure 34*, texting, dialing/talking/hanging up, and selecting an FM/AM station are higher in value but not significant enough to have valid statistical difference.

Expanded Estimates

Nominal factors expanded to all levels

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-2.498432	0.156487	-15.97	<.0001*
Distraction[Adjusting dashboard contols]	-0.367378	0.491521	-0.75	0.4720
Distraction[Answering/Talking/Hanging up]	-0.498549	0.491521	-1.01	0.3344
Distraction[Cell Phone Texting]	0.3753582	0.491521	0.76	0.4627
Distraction[Cell Phone touch screen (Pandora)]	-0.483282	0.491521	-0.98	0.3487
Distraction[Charging ,read out Facebook]	0.157478	0.527046	0.30	0.7712
Distraction[Dialing/Talking/Hanging up]	0.7890263	0.542088	1.46	0.1762
Distraction[Eating-Drinking]	0.0164906	0.527046	0.03	0.9757
Distraction[FM/AM station selection]	0.7068649	0.491521	1.44	0.1810
Distraction[GPS]	0.3699899	0.491521	0.75	0.4690
Distraction[Grooming]	-0.705196	0.527046	-1.34	0.2105
Distraction[Passenger Conversation]	-0.360803	0.542088	-0.67	0.5207
Gender[F]	-0.15554	0.210298	-0.74	0.4765
Gender[M]	0.1555404	0.210298	0.74	0.4765

Figure 34: Parameter Estimates of Y=Log SD Lane Position (Road Segment 2), X=Distractions, Gender

"Road Segment 2" with no event: factors that affect log SD velocity. Both P-values for distraction and gender are not significant and therefore are not found important, as shown in *Figure 35*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	5.3073718	0.3479	0.9445
Gender	1	1	0.5776294	0.3787	0.5521

Figure 35: Effect Tests of Y=Log SD Velocity (Road Segment 2), X=Distractions, Gender

"Road Segment 2" with no event: factors that affect mean velocity. Both P-values for distraction (P=0.73) and gender (P=0.79) from *Figure 36* were not significant and therefore were not found important.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	23.449364	0.6712	0.7300
Gender	1	1	0.256977	0.0736	0.7917

Figure 36: Effect Tests of Y=Mean Velocity (Road Segment 2), X=Distractions, Gender

"Road Segment 3" Road Condition. Log SD lane position, log SD velocity, and mean velocity for "Road Segment 3" road condition were investigated for 22 data. Males demonstrated worse driving behavior in all of the response variables although only log SD velocity was statistically significant. FM/AM station selection was found to be a highly dangerous distraction in the SD velocity variable, with P-value= 0.03 and t ratio=2.42.

"Road Segment 3" with no event: factors that affect log SD lane position. Based on *Figure 37*, both P-values for distraction (P=0.23) and gender (P=0.30) were not significant and therefore were not found to be important. However, GPS had a significantly lower value than the others, meaning that driving in "Road Segment 3" road condition using a GPS had the least amount of variation in lane position and was least affected.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	5.1269891	1.5966	0.2363
Gender	1	1	0.3716339	1.1573	0.3073

Expanded Estimates

Nominal factors expanded to all levels

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-3.082376	0.122179	-25.23	<.0001*
Distraction[Adjusting dashboard contols]	-0.251993	0.382482	-0.66	0.5249
Distraction[Answering/Talking/Hanging up]	0.4209591	0.440147	0.96	0.3614
Distraction[Cell Phone Texting]	-0.761031	0.423241	-1.80	0.1024
Distraction[Cell Phone touch screen (Pandora)]	0.6488972	0.382482	1.70	0.1206
Distraction[Charging ,read out Facebook]	-0.754474	0.423241	-1.78	0.1050
Distraction[Dialing/Talking/Hanging up]	0.4182053	0.382482	1.09	0.2999
Distraction[Eating-Drinking]	0.2567098	0.423241	0.61	0.5577
Distraction[FM/AM station selection]	0.4104253	0.440147	0.93	0.3731
Distraction[GPS]	-1.106584	0.423241	-2.61	0.0258*
Distraction[Grooming]	0.3305593	0.440147	0.75	0.4699
Distraction[Passenger Conversation]	0.3883255	0.382482	1.02	0.3339
Gender[F]	-0.215532	0.200348	-1.08	0.3073
Gender[M]	0.2155324	0.200348	1.08	0.3073

Figure 37: Effect Tests and Parameter Estimates of Y=Log SD Lane Position (Road Segment 3), X=Distractions, Gender

The model's R-Square is 0.63, and male drivers drove worse based solely on numerical values, as shown in *Figure 38*.

Summary of Fit

RSquare	0.626252
RSquare Adj	0.215128
Root Mean Square Error	0.566668
Mean of Response	-3.06278
Observations (or Sum Wgts)	22

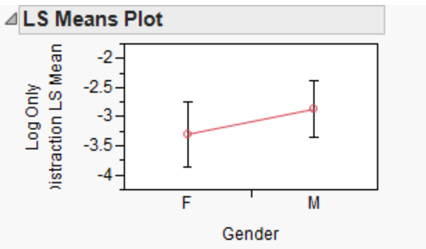


Figure 38: Fit Summary and Gender Plot of Y=Log SD Lane Position (Road Segment 3), X=Distractions, Gender

"Road Segment 3" with no event: factors that affect Log SD velocity. Gender was a significant factor (P-value = 0.03), and males had statistically higher Log SD velocity values than females, as illustrated in *Figure 39*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	10.816689	1.5474	0.2512
Gender	1	1	4.215094	6.0298	0.0339*

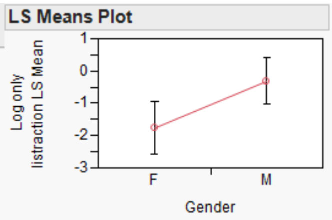


Figure 39: Effect Tests and Gender Plot of Y=Log SD Velocity (Road Segment 3), X=Distractions, Gender

Some, some distractions were found to be significantly different from others. For example, FM/AM station selection had a very high Log SD velocity, whereas using a GPS had the lowest amount of variation in this variable, as shown in *Figure 40*.

Expanded Estimates

Nominal factors expanded to all levels

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1.040923	0.180269	-5.77	0.0002*
Distraction[Adjusting dashboard contols]	-0.530417	0.56433	-0.94	0.3694
Distraction[Answering/Talking/Hanging up]	1.1682005	0.649412	1.80	0.1022
Distraction[Cell Phone Texting]	-0.491352	0.624469	-0.79	0.4496
Distraction[Cell Phone touch screen (Pandora)]	-0.428215	0.56433	-0.76	0.4655
Distraction[Charging ,read out Facebook]	-0.991487	0.624469	-1.59	0.1434
Distraction[Dialing/Talking/Hanging up]	0.2957341	0.56433	0.52	0.6117
Distraction[Eating-Drinking]	0.4077644	0.624469	0.65	0.5285
Distraction[FM/AM station selection]	1.5695099	0.649412	2.42	0.0363*
Distraction[GPS]	-1.581221	0.624469	-2.53	0.0298*
Distraction[Grooming]	0.7589685	0.649412	1.17	0.2696
Distraction[Passenger Conversation]	-0.177486	0.56433	-0.31	0.7596
Gender[F]	-0.72587	0.295601	-2.46	0.0339*
Gender[M]	0.7258697	0.295601	2.46	0.0339*

Figure 40: Parameter Estimates of Y=Log SD Velocity (Road Segment 3), X=Distractions, Gender

"Road Segment 3" with no event: factors that affect mean velocity. Both P-values for distraction (P=0.57) and gender (P=0.11) are not significant and therefore are not found to be important based on *Figure 41*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	36.143111	0.8889	0.5720
Gender	1	1	11.999037	2.9511	0.1166

Figure 41: Effect Tests of Y=Mean Velocity (Road Segment 3), X=Distractions, Gender

"Road Segment 4" Road Condition. Log SD lane position, Log SD velocity, and mean velocity in "Road Segment 4" road condition were investigated for 22 data. In two out of three variables, male drivers drove worse than female drivers. However, this finding was not statistically significant in any of the three models.

"Road Segment 4" with no event: factors that affect Log SD lane position. The P-values of gender and distraction factors are 0.71 and 0.72, respectively, meaning they were not statistically important, as illustrated in *Figure 42*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	0.1250368	0.1348	0.7211
Distraction	10	10	6.4220352	0.6925	0.7140

Figure 42: Effect Tests of Y=Log SD Lane Position (Road Segment 4), X=Distractions, Gender

"Road Segment 4" with no event: factors that affect Log SD velocity.The P-values of gender and distraction factors were 0.36 and 0.77, respectively, meaning they were not statistically important, as illustrated in *Figure 43*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	1.9633995	0.6188	0.7694
Gender	1	1	0.2827872	0.8912	0.3674

Figure 43: Effect Tests of Y=Log SD Velocity (Road Segment 4), X=Distractions, Gender

"Road Segment 4" with no event: factors that affect mean velocity. The P-values of gender and distraction factors were 0.74 and 0.94, respectively, meaning they are not statistically important, as illustrated in *Figure 44*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	15.122443	0.3570	0.9402
Gender	1	1	0.485763	0.1147	0.7419

Figure 44: Effect Tests of Y=Mean Velocity (Road Segment 4) , X=Distractions, Gender

"Road Segment 5" Road Condition. Log SD lane position, Log SD velocity, and mean velocity in "Road Segment 5" were analyzed for 22 data. In this road condition, female drivers drove worse than male drivers for all of the response variables. However, the difference was not found to be statistically significant. No distractions were found important in this road condition.

"Road Segment 5" with no event: factors that affect Log SD lane position. The P-values of gender and distraction factors are 0.61 and 0.95, respectively, meaning they were not statistically important. Numerically, females drove worse than males and had more variation in their position while driving. The plots for both distractions and gender are shown in *Figure 45*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	0.91578476	0.3250	0.9546
Gender	1	1	0.07725257	0.2742	0.6120

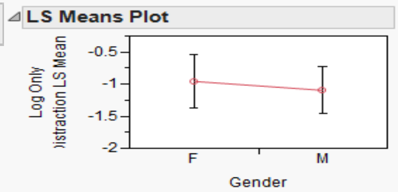


Figure 45: Effect Tests and Gender Plot of Y=Log SD Lane position (Road Segment 5), X=Distractions, Gender

"Road Segment 5" with no event: factors that affect Log SD velocity. The P-values of gender and distraction factors are 0.79 and 0.87, respectively, meaning they are not statistically important, as shown in *Figure 46*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	0.97022590	0.4676	0.8768
Gender	1	1	0.01499044	0.0722	0.7936

Figure 46: Effect Tests of Y=Log SD Velocity (Road Segment 5), X=Distractions, Gender

"Road Segment 5" with no event: factors that affect mean velocity. The P-values of gender and distraction factors are 0.30 and 0.17, respectively, meaning they are not statistically important, as shown in *Figure 47*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	7.9154589	1.8412	0.1751
Gender	1	1	0.4995955	1.1621	0.3064

Figure 47: Effect Tests of Y=Mean Velocity (Road Segment 5), X=Distractions, Gender

Factors that Affect Teenage Driving Performance Given Fixed Road Conditions with Events

The analysis focused on event and distraction location as shown in *Figure 48*. Based on previous results, the analysis was implemented for each road condition separately (i.e., Road Segment 1, Road Segment 2, Road Segment 3, Road Segment 4, Road Segment 5) with the independent variables being gender and distractions. *Figure 49* shows distractions and gender for 22 data for analysis.

No Distraction	Only Distraction	Event and Distraction

Figure 48: Road Divisions

Locaiton	Road Segment 1	Locaiton	Road Segment 1
1A	GPS	1B	Driver Initiated Conversation
2A	Cell Phone touch screen (Pandora)	2B	Cell Phone Texting
3A	Answering/Talking/Hanging up	3B	Adjusting dashboard contols
4A	Cell Phone Texting	4B	Grooming
5A	Dialing/Talking/Hanging up	5B	Radio
6A	Grooming	6B	Charging ,read out Facebook
7A	Charging ,read out Facebook	7B	GPS
8A	Driver Initiated Conversation	8B	Cell Phone touch screen (Pandora)
9A	Eating/Drinking	9B	Dialing/Talking/Hanging up
10A	Adjusting dashboard contols	10B	Eating/Drinking
11A	Radio	11B	Answering/Talking/Hanging up

Figure 49: Road Segment 1

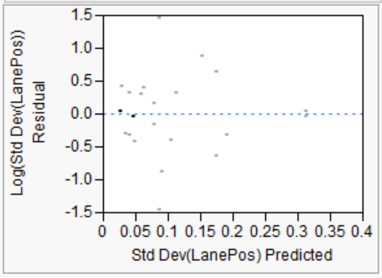
Road Segment 1 and Dog Event. In road segment 1 with the dog event, the following response variables were investigated for 22 data: Log SD lane position, CV headway distance, Log SD velocity and mean velocity. Coefficient of variation in headway distance was used because this variable parameter could show the extent of variability much better in relation to mean. Female drivers drove worse than male drivers in lane position and CV headway distance. This finding was based solely on gender plot and was not found to be statistically significant. Moreover, grooming and answering/talking/hanging-up were statistically significant in the model for log SD lane position and CV headway distance, respectively. Also, distraction had a P-value of 0.094 in CV headway distance; and if alpha at the level of 0.1 were considered, distraction would be statistically significant.

"Road Segment 1" and dog event: factors that affect log SD lane position. In "Road Segment 1" where a dog suddenly jumped in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD lane position. The P-values of gender and distraction factors were 0.32 and 0.33 respectively. Therefore, they were not statistically important, but the grooming distraction had a significantly high log SD lane position, as illustrated in *Figure 50*.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Distraction	10	10	10	1.3181	0.3353
Gender	1	1	10	1.0817	0.3228

Residual by Predicted Plot



Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	-2.476905	0.19071	10	-12.99	<.0001*
Distraction[Adjusting dashboard contols]	0.5461031	0.599014	10	0.91	0.3834
Distraction[Answering/Talking/Hanging up]	0.2033296	0.642308	10	0.32	0.7581
Distraction[Cell Phone Texting]	0.3279657	0.599014	10	0.55	0.5960
Distraction[Cell Phone touch screen (Pandora)]	-0.238395	0.660639	10	-0.36	0.7257
Distraction[Charging ,read out Facebook]	-0.868658	0.599014	10	-1.45	0.1776
Distraction[Dialing/Talking/Hanging up]	0.4623793	0.660639	10	0.70	0.4999
Distraction[Driver Initiated Conversation]	-0.498276	0.642308	10	-0.78	0.4558
Distraction[Eating/Drinking]	-0.836004	0.599014	10	-1.40	0.1930
Distraction[GPS]	-0.04886	0.599014	10	-0.08	0.9366
Distraction[Grooming]	1.5759782	0.642308	10	2.45	0.0340*
Gender[F]	0.2665511	0.256289	10	1.04	0.3228

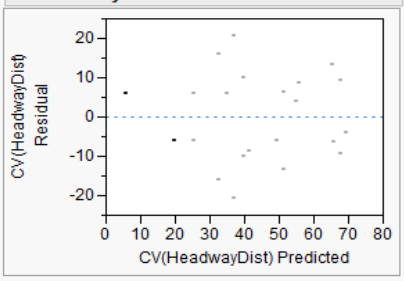
Figure 50: Effect Tests and Parameter Estimates of Y=Log SD Lane Position (Road Segment 1 and Dog Event), X=Distractions, Gender

"Road Segment 1" and dog event: factors that affect CV headway distance. In "Road Segment 1" where a dog suddenly jumped in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on CV headway distance. The obtained P-values of gender and distraction were 0.15 and 0.09 respectively, which mean they were not statistically important. The P-value of distraction (0.09) means that with a higher α level such as 0.10, this factor would have been considered important. Moreover, distractions such as "answering/talking/hanging-up" had a high coefficient of variation for headway distance. Conversely, charging a cellphone and reading Facebook had a very low value. The P-value and plot of distractions are shown in *Figure 51*.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Distraction	10	10	10	2.3751	0.0943
Gender	1	1	10	2.3802	0.1539

Residual by Predicted Plot



Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	44.602687	3.456336	10	12.90	<.0001*
Distraction[Adjusting dashboard contols]	3.6983701	10.85623	10	0.34	0.7404
Distraction[Answering/Talking/Hanging up]	30.216014	11.64087	10	2.60	0.0267*
Distraction[Cell Phone Texting]	13.654689	10.85623	10	1.26	0.2371
Distraction[Cell Phone touch screen (Pandora)]	-19.22349	11.9731	10	-1.61	0.1395
Distraction[Charging ,read out Facebook]	-32.03014	10.85623	10	-2.95	0.0145*
Distraction[Dialing/Talking/Hanging up]	-12.10683	11.9731	10	-1.01	0.3358
Distraction[Driver Initiated Conversation]	-0.566588	11.64087	10	-0.05	0.9621
Distraction[Eating/Drinking]	-2.574477	10.85623	10	-0.24	0.8173
Distraction[GPS]	13.619504	10.85623	10	1.25	0.2382
Distraction[Grooming]	-12.04458	11.64087	10	-1.03	0.3252
Gender[F]	7.16596	4.644845	10	1.54	0.1539

Figure 51: Effect Tests and Parameter Estimates of Y= CV Headway Distance (Road Segment 1 and Dog Event), X=Distractions, Gender

"Road Segment 1" and dog event: factors that affect log SD velocity.In "Road Segment 1" where a dog suddenly jumped in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD velocity. The obtained P-value of gender is 0.73 and distractions, 0.73 which means they are not statistically important, as shown in *Figure 52*.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Distraction	10	10	10	0.6705	0.7306
Gender	1	1	10	0.1244	0.7317

Figure 52: Effect Tests of Y= LOG SD Velocity (Road Segment 1 and Dog Event), X= Gender, Distraction

"Road Segment 1" and dog event: factors that affect mean velocity. In "Road Segment 1" where a dog suddenly jumped in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on mean velocity. In the fixed-effect tests, both distraction and gender were not significant with P-values of 0.7 and 0.55, respectively. Numerically, males drove faster than females as shown in *Figure 53.*

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Distraction	10	10	10	0.7046	0.7049
Gender	1	1	10	0.3769	0.5530

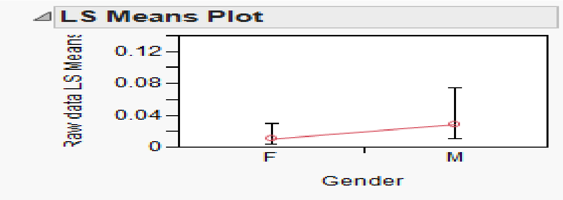
Least Squares Means Table

Level	Least Sq Mean	Std Error
F	20.299172	1.4264938
M	21.628708	1.2682775

Figure 53: Effect Tests and Gender Table of Y=Mean Velocity (Road Segment 1 and Dog Event), X=Distractions, Gender

Road Segment 2 and Kid Event. Different response variables, such as log SD lane position, CV headway distance, log SD velocity and mean velocity are known for presenting bad driving behavior and were used in the model. These data were collected for event and distraction in Road Segment 2 road condition. To analyze their significance in the model, the inputs of gender and distraction were included.

"Road Segment 2" and kid event: factors that affect SD Lane Position. In "Road Segment 2" where kids were passing the road, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD lane position. The P-values of gender and distraction factors were 0.19 and 0.87 respectively, as shown in *Figure 54*. Therefore, they were not statistically important.

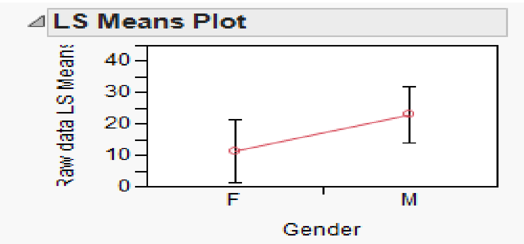


Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	7.7425253	0.4805	0.8683
Gender	1	1	3.1776980	1.9720	0.1905

Figure 54: Effect Tests and Gender Plot of Y=Log SD Lane Position (Road Segment 2 and Kids Event), X=Distractions, Gender

"Road Segment 2" and kid event: factors that affect CV headway distance. In "Road Segment 2" where kids were passing the road, data was analyzed to see which of the gender and distraction factors have statistically significant effects on CV headway distance *Figure 55* shows that P-value for distraction and gender were 0.92 and 0.12, respectively, and therefore were not significant. Numerically, male drivers showed higher CV headway distance.



Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	404.02240	2.8464	0.1225
Distraction	10	10	554.69085	0.3908	0.9228

Figure 55: Effect Tests and Gender Plot of Y= CV Headway Distance (Road Segment 2 and Kids Event), X=Distractions, Gender

"Road Segment 2" and kid event: factors that affect log SD velocity. In "Road Segment 2" road condition in which kids were passing the road, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD velocity. *Figure 56*, the effect-tests table, shows that P-value for distraction and gender are 0.93 and 0.77, respectively, and were not significant.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	17.659621	0.6121	0.7744
Gender	1	1	0.020190	0.0070	0.9350

Figure 56: Effect Tests of Y=Log SD Velocity (Road Segment 2 and Kids Event), X=Distractions, Gender

"Road Segment 2" and kid event: factors that affect mean velocity. In "Road Segment 2" road condition when kids were passing the road, data was analyzed to see which of the gender and distraction factors have statistically significant effects on mean velocity.

This case included 22 observations. For Road Segment 2's road condition and for mean velocity, no important factors were found, as shown in *Figure 57*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distraction	10	10	64.546752	0.4126	0.9106
Gender	1	1	17.845122	1.1406	0.3106

Figure 57: Effect Tests of Y=Mean Velocity (Road Segment 2 and Kids Event), X=Distractions, Gender

Road Segment 4 and Ambulance Event. Different response variables, such as Log SD lane position, CV headway distance, log SD velocity and mean velocity, which are representatives of bad driving behaviors, were used in the model. Gender and distraction were analyzed to determine if they were significant in the model.

"Road Segment 4" and ambulance event: factors that affect log SD lane position.In "Road Segment 4" road condition when an ambulance suddenly came in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD lane position. Factors such as distraction and gender were not found to be significant due to their high P-values, as shown in *Figure 58*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
distraction	10	10	4.6933364	0.6472	0.7370
Gender	1	1	0.0673999	0.0929	0.7804

Figure 58: Effect Tests of Y=SD Lane Position (Road Segment 4 and Ambulance Event)-X=Distractions, Gender

"Road Segment 4" and ambulance event: factors that affect CV headway distance. In "Road Segment 4" road condition when an ambulance suddenly came in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on CV headway distance. A large amount of variation is shown in this model based on high R-Square (0.98), as illustrated in *Figure 59*.

Summary of Fit

RSquare	0.984965
RSquare Adj	0.929838
Root Mean Square Error	1.016813
Mean of Response	5.418846
Observations (or Sum Wgts)	15

Figure 59- Fit Summary of CV Headway Distance (Road Segment 4 and Ambulance Event), X=Distractions, Gender

The effect tests shows that distraction was an important factor with a P-value of 0.01 and an F ratio of 19.6, as shown in *Figure 60*. Distraction can lead to change in headway distance behavior, causing it to worsen. The gender factor, as shown in *Figure 60*, was not significant due to the P-value of 0.24. Numerically, male drivers drove better than female drivers, but the model did not find that this difference was statistically significant.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
distraction	10	10	202.63360	19.5988	0.0161*
Gender	1	1	2.23710	2.1637	0.2377

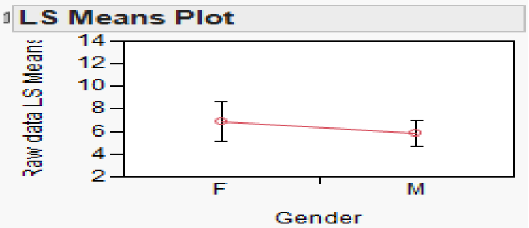


Figure 60: Effect Tests and Gender Plot of CV Headway Distance (Road Segment 4 and Ambulance Event), X=Distractions, Gender

Grooming, passenger conversation, and FM/AM station selection were three distractions that were significantly higher than others as referenced in *Figure 61*, the leverage table for distraction.

Level				Least Sq Mean
Passenger Conversation	A			13.716141
FM/AM station selection	A	B		12.805313
Grooming	A	B	C	11.010171
Charging ,read out Facebook	A	B	C	7.611678
Answering/Talking/Hanging up	A	B	C	5.260568
Cell Phone touch screen (Pandora)	A	B	C	4.054956
Adjusting dashboard contols		B	C	4.040360
Eating-Drinking			C	3.292415
Dialing/Talking/Hanging up			C	3.136126
GPS			C	2.726567
Cell Phone Texting			C	2.372955

Levels not connected by same letter are significantly different.

Figure 61: Leverage Table of Y= CV Headway Distance (Road Segment 4 and Ambulance Event), X=Distractions, Gender

"Road Segment 4" and ambulance event: factors that affect log SD velocity. In "Road Segment 4" road condition when an ambulance suddenly came in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on log SD velocity Based on the effect test table in *Figure 62*, both distraction and gender were not found to be significant. The P-value for distraction was 0.34, and 0.81 was the P-value for gender.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	0.0193346	0.0695	0.8092
Distraction	10	10	5.1440825	1.8486	0.3350

Effect Tests

Figure 62: Effect Tests of Y=Log SD Velocity (Road Segment 4 and Ambulance Event), X=Distractions, Gender

"Road Segment 4" and ambulance event: factors that affect mean velocity.In Road Segment 4 road condition when an ambulance suddenly came in front of the car, data was analyzed to see which of the gender and distraction factors have statistically significant effects on mean velocity Distractions and gender did not play a significant role in describing mean velocity. The conclusion was derived from the effect tests table in which the P-values for distractions and gender were 0.35 and 0.81, respectively, as shown in *Figure 63*.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
distraction	10	10	42.280537	1.7254	0.3584
Gender	1	1	0.160457	0.0655	0.8146

Figure 63: Effect Tests of Y=Mean Velocity (Road Segment 4 and Ambulance Event), X=Distractions, Gender

Distractions Ranking

Unexpected events in the experiments enhanced the distractions' effects. Therefore, only event and distraction locations for Road Segment 1 and Dog Event, Road Segment 4 and Ambulance Event, and Road Segment 2 and Kids Event were considered for ranking. Ranking was based on the values of standard deviation of velocity, standard deviation of lane position, coefficient of variation of headway distance, and mean velocity. In each of the mentioned event and distraction locations, distractions were ranked from 0 to 10 for each driving performance. The highest value for each performance variable was assigned the highest rank, which represented the most dangerous distraction. This ranking was done for each road condition; for example, lane position for Road Segment 1 is shown below in *Table 13*. For each variable/parameter indicating dangerous driving behavior (e.g. SD lane position), distractions were ranked based on their values. *Table* 13 is a small part of the entire ranking table.

Table 13: Ranking Table for SD Lane Position and Road Segment 1 and Dog Event

Distraction	Rank	Gender	Driver	Parameter	Event	Raw data
Grooming	0.45	M	4BMS	chart SD lane position	Dog	0.091
Dialing/Talking/Hanging up	0.91	F	9BMS	chart SD lane position	Dog	0.102
FM/AM station selection	1.36	M	5BMS	chart SD lane position	Dog	0.133
Answering/Talking/Hanging up	1.82	M	11BMS	chart SD lane position	Dog	0.177
Answering/Talking/Hanging up	2.27	M	3AMS	chart SD lane position	Dog	0.188
Charging a cellphone, read out Facebook	2.73	F	7AMS	chart SD lane position	Dog	0.193
Cell Phone Texting	3.18	M	4AMS	chart SD lane position	Dog	0.194
Passenger Conversation	3.64	M	1BMS	chart SD lane position	Dog	0.204
Passenger Conversation	4.09	M	8AMS	chart SD lane position	Dog	0.207
Eating-Drinking	4.55	F	9AMS	chart SD lane position	Dog	0.216
Eating-Drinking	5.00	M	10BMS	chart SD lane position	Dog	0.217
Cell Phone touch screen (Pandora)	5.45	F	2AMS	chart SD lane position	Dog	0.241
Charging, read out Facebook	5.91	M	6BMS	chart SD lane position	Dog	0.254
GPS	6.36	M	1AMS	chart SD lane position	Dog	0.285
Grooming	6.82	M	6AMS	chart SD lane position	Dog	0.318

After ranking distractions for each of the driving-performance variables (i.e., standard deviation of velocity, standard deviation of lane position, coefficient of variation of headway distance, and mean velocity) in each unexpected event area (i.e., Road Segment 1 and Dog Event," Road Segment 2 and Kids Event, and Road Segment 3 and Ambulance Event), the mean of distraction ranks were calculated as shown in *Table 14,* which also contains each driver's effect on ranking.

Table 14: Rank of Dangerous Distractions Based on Average of Driving Performane

Distraction	Average Sum of Rank
Eating-Drinking	4.27
Charging, read out Facebook	4.69
Grooming	4.76
Adjusting dashboard controls	4.93
Cell Phone touch screen (Pandora)	5.09
GPS	5.45
Cell Phone Texting	5.51
Passenger Conversation	5.58
Dialing/Talking/Hanging up	5.64
Answering/Talking/Hanging up	5.77
FM/AM station selection	6.20

To have a more accurate understanding of distractions' effect, the driver was put as a random variable in the model. The ranking result based on treating drivers as a random effect is shown in *Table 15* and *Figure 64*.

Table 15: Rank of dangerous distractions Based on Least Square Mean of Driving Performane Model

Distraction	Least Square Mean of Rank
Grooming	4.21
Eating-Drinking	4.34
Adjusting dashboard controls	4.99
Cell Phone touch screen (Pandora)	5.03
GPS	5.13
Charging, read out Facebook	5.16
Passenger Conversation	5.44
Answering/Talking/Hanging up	5.63
Cell Phone Texting	5.82
Dialing/Talking/Hanging up	5.91
FM/AM station selection	6.42

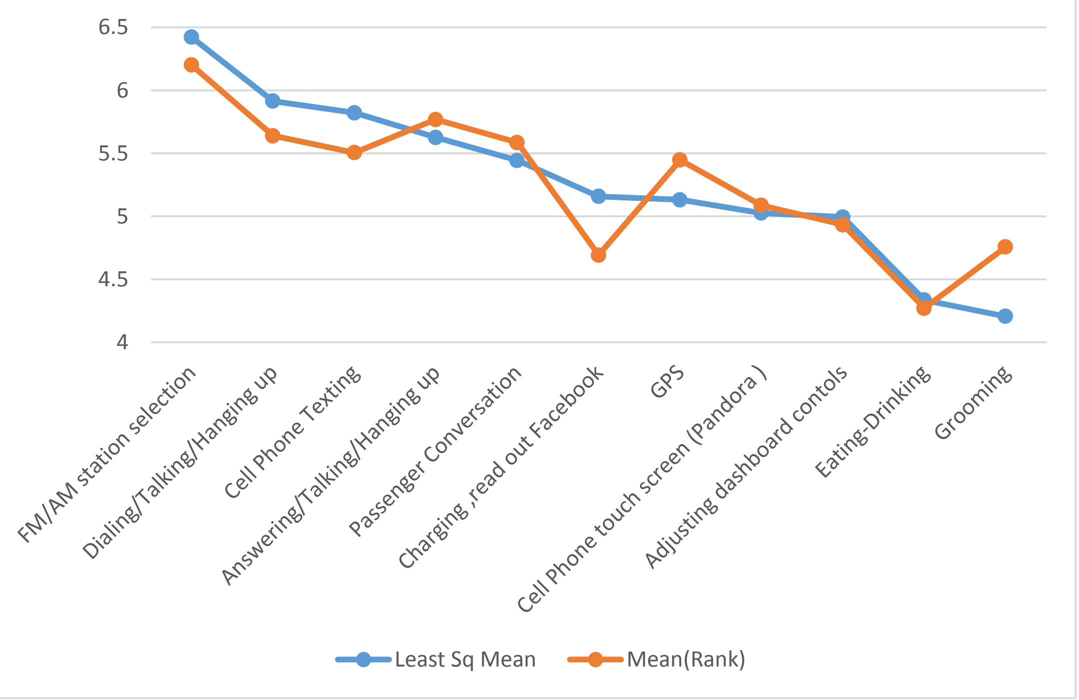


Figure 64: Ranking of Distractions

Chapter 5

Conclusion and Future Work

With the presence of gender, road condition and distraction factors, the road condition was found to be statistically important for each response variable. The effect of road condition was so strong that other factors were not found statistically significant. Therefore, road condition remained fixed in the rest of the analysis. Moreover, to increase the effect of distraction factor, an event was introduced that led to increased mental workload. To observe distractions' effect on all the response variables combined and to decrease type I error due to high number of tests, a mixed model for ranking was used.

Performance Decrement, Road Condition Factor

For five different road conditions, ANOVA was used for 110 observations for "Only Distraction" locations. Road condition was found to have statistically significant effects on mean velocity, SD lane position and SD velocity. The location of "Road Segment 5" had the highest lane-position variation and velocity variation. This area was in a rural location, and the weather was snowy. Teenage drivers in the presense of distractions had more difficulty in lane keeping and speed control on a curvy and snowy road than a straight road.

Performance Decrement, Gender

Using ANOVA for each road condition in the "Only Distraction" location helped to show that the other input factor, gender, was important. *Table 16* shows the locations and response variables where gender was found to be significant. For example, in the analysis of SD velocity, males had more variation than females (F(1)=6.03,P=0.03). Therefore, gender was an important factor for driving behavior, and variables that were representative of bad driving behavior were worse for male drivers. Distractions such as texting and changing a radio station were found to be important in the "Road Segment 1," which was a suburban location. Also shown in *Table 16*, changing a radio station had high variation in velocity. In "Road Segment 1" and "Road Segment 3," male drivers drove faster than female drivers. Lane position variation was not found to be significant for each road condition in the "Only Distraction" location.

Table 16: Summary of "Only Distraction" Location Results

Road Condition	Only Distraction Location		
	Response Variable	Significant Factor	Risky Distraction
Road Segment 1	Mean velocity	Gender (F(1)=3.52,P=0.09)	Texting(t(10)=2.47,P=0.03)
Road Segment 3	Log SD Velocity	Gender*(F(1)=6.03,P=0.03)	Changing a radio station(t(10)=2.42,P=0.04)
	Mean Velocity	Gender(F(1)=2.95 ,P=0.11)	-

Performance Decrement, Distractions

Using ANOVA analysis in the "Event and Distraction" locations, the distraction factor (P.Value=0.016) was important for CV headway distance in the "Road Segment 4" (city). Answering/talking/hanging up, grooming, changing a radio station, and conversing with a passenger were all found to be statistically important for variables CV headway distance and SD lane position. *Table 17* shows a summary of results in the "Event and Distraction" location.

Table 17: Summary of "Event and Distraction" Location Results

Road Condition/Event	Event and Distraction Location		
	Response Variable	Significant Factor	Risky Distraction
Road Segment 1 and Dog Event	SD Lane Position	-	Grooming (t(10)=2.45,P=0.03)
	CV Headway Distance	Distraction* (F(10)=2.38,P=0.09)	Answering/talking/hanging up a call (t(10)=2.6,P=0.03)
Road Segment 4 and Ambulance Event	CV Headway Distance	Distraction* (F(10)=19.60,P=0.02)	Grooming (t(10)=4.36,P=0.02) Changing a radio station (t(10)=6.47,P=0.007) Verbal conversation to passenger (t(10)=7.38,P=0.005)

Ranking

Descriptive statistics ranking was used to find the most dangerous distractions. In addition,findings from ANOVA and the eleven distractions were listed based on their severity and effect on bad driving behaviour variables. Changing a radio station, dialing/talking/hanging-up, texting, answering/talking/hanging-up a call, and conversing with a passenger were the top-five dangerous distractions in order.

Consistency among ranking, ANOVA

Table 18 shows a consistency between the ANOVA and ranking results. *Table 19* also shows distractions involving cognitive, auditory and visual distractions, which were found to be more dangerous in the ANOVA and ranking methods.

Table 18: Consistency Among Three Methods

Distraction	Ranking	ANOVA
Changing a radio station	x (1)	x
Dialing/Talking/Hanging up	x (2)	
Texting	x (3)	x
Answering/Talking/Hanging up	x (4)	x
Verbal conversation to passenger	x (5)	x
Grooming		x

Table 19: Top-Five Most Dangeous Distractions (Highlighted)

Distractions	Cognitive	Visual	Biomechanical	Auditory
Verbal conversation to passenger	1	2		4
Dialing/talking/hanging up	1	2	3	4
Changing a radio station	1	2	3	
Texting	1	2	3	
Adjusting dashboard controls	1	2	3	
Answering/talking/hanging up a call	1		3	4
Plugging cellphone to charge and pulling up Facebook		2	3	
Using GPS		2	3	
Cell phone touch screen (Pandora)		2	3	
Grooming			3	
Eating and drinking			3	

Future Work

This research has provided insight to analyze factors, such as distractions, gender, and road condition. A new experiment design with fewer factors and more replications is suggested and developed as shown in *Figure 65*.

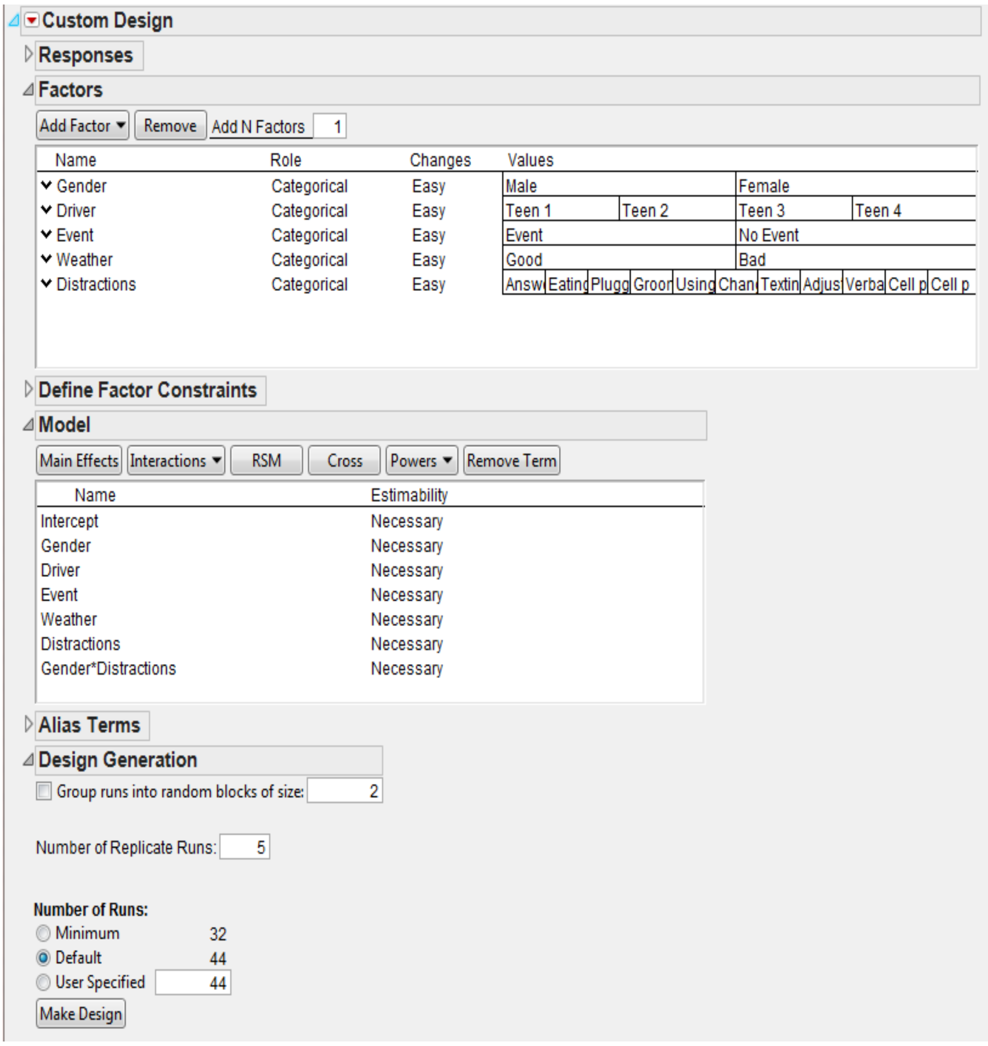


Figure 65: DOE for Future Study

An example of DOE from *Figure 62* is shown in *Table 20*, which includes factors and their level for a limited number of runs.

Table 20: Future DOE Table

Gender	Driver	Event	Weather	Distractions
Female	Teen 2	Event	Good	Texting
Male	Teen 3	No Event	Bad	Verbal conversation to passenger
Female	Teen 4	Event	Good	Eating and drinking
Male	Teen 4	No Event	Good	Adjusting dashboard controls
Female	Teen 3	No Event	Good	Verbal conversation to passenger
Male	Teen 1	No Event	Bad	Changing a radio station
Male	Teen 4	Event	Good	Grooming
Male	Teen 4	No Event	Bad	Answering/talking/hanging up a call
Male	Teen 3	Event	Good	Cell phone touch screen (Pandora)
Female	Teen 3	No Event	Good	Verbal conversation to passenger
Male	Teen 1	Event	Good	Plugging cellphone to charge and accessing Facebook

Table 20: Continued

Gender	Driver	Event	Weather	Distractions
Female	Teen 4	Event	Bad	Using GPS
Male	Teen 3	No Event	Bad	Grooming
Female	Teen 1	No Event	Bad	Texting
Male	Teen 2	Event	Good	Verbal conversation to passenger
Female	Teen 2	No Event	Bad	Changing a radio station
Male	Teen 1	No Event	Bad	Changing a radio station
Male	Teen 3	Event	Good	Answering/talking/hanging up a call
Male	Teen 1	No Event	Bad	Texting
Female	Teen 4	No Event	Bad	Adjusting dashboard controls
Male	Teen 3	No Event	Bad	Dialing/talking/hanging-up
Female	Teen 4	Event	Good	Eating and drinking
Female	Teen 2	Event	Bad	Grooming
Female	Teen 1	No Event	Bad	Answering/talking/hanging up a call
Male	Teen 1	No Event	Good	Eating and drinking
Female	Teen 1	No Event	Bad	Answering/talking/hanging up a call
Male	Teen 3	No Event	Bad	Using GPS
Male	Teen 2	No Event	Bad	Plugging cellphone to charge and pulling up Facebook
Female	Teen 2	Event	Bad	Verbal conversation to passenger
Female	Teen 1	Event	Good	Adjusting dashboard controls
Female	Teen 1	Event	Bad	Cellphone touch screen (Pandora)
Male	Teen 3	Event	Bad	Eating and drinking
Male	Teen 3	No Event	Bad	Using GPS
Female	Teen 4	Event	Good	Changing a radio station
Female	Teen 2	No Event	Good	Cellphone touch screen (Pandora)
Female	Teen 4	Event	Bad	Plugging cellphone to charge and pulling up Facebook
Male	Teen 1	Event	Good	Dialing/talking/hanging-up
Female	Teen 2	No Event	Good	Plugging cellphone to charge and pulling up Facebook
Female	Teen 1	No Event	Good	Using GPS
Male	Teen 3	Event	Good	Texting
Female	Teen 1	Event	Bad	Cell phone (dialing/talking/hanging-up)
Female	Teen 4	No Event	Good	Cell phone (dialing/talking/hanging-up)
Female	Teen 4	No Event	Good	Grooming
Male	Teen 4	No Event	Bad	Cell phone touch screen (Pandora)

List of References

Burns, P. C., Parkes, A., Burton, S., Smith, R. K., & Burch, D. (2002). How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol. Transport Research Laboratory.

Consiglio, W., Driscoll, P., Witte, M., & Berg, W. P. (2003). Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. Accident Analysis & Prevention, 35(4), 495-500. Doi: http://dx.doi.org/10.1016/S0001-4575(02)00027-1

Donmez, B., Boyle, & Lee. (2007). Safety implications of providing real-time feedback to distracted drivers. Accident Analysis & Prevention, 39(3), 581-590. doi: http://dx.doi.org/10.1016/j.aap.2006.10.003

Drews (2004). Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers. human factors.

Fairclough, S. H., May, A, & Carter, C. (1997). The effect of time headway feedback on following behaviour. Accident Analysis & Prevention, *29*(3), 387-397. doi: http://dx.doi.org/10.1016/S0001-4575(97)00005-5

The Federal Highway Administration. (2013). Distribution of licensed drivers - 2011 by sex and percentage in each age group and relation to population.

Ferguson, S. A. (2003). Other high-risk factors for young drivers—how graduated licensing does, doesn't, or could address them. J Safety Res, 34(1), 71-77. doi: http://dx.doi.org/10.1016/S0022-4375(02)00082-8

Finn, P., & Bragg, B. W. E. (1986). Perception of the risk of an accident by young and older drivers. Accident Analysis & Prevention, 18(4), 289-298. doi: http://dx.doi.org/10.1016/0001-4575(86)90043-6

Ginsburg, K. R., Winston, F. K., Senserrick, T. M., García-España, F., Kinsman, S., Quistberg. Elliott, M. R. (2008). National young-driver survey: teen perspective and experience with factors that affect driving safety. Pediatrics, 121(5), e1391-e1403.

Greenberg, J., Tijerina, L., Curry, R., Artz, B., Cathey, L., Kochhar, Grant, P. (2003). Driver Distraction: Evaluation with Event Detection Paradigm. Transportation Research Record: Journal of the Transportation Research Board, 1843(-1), 1-9. doi: 10.3141/1843-01

Horberry, Anderson, Regan, M. A., Triggs, & Brown, J. (2006). Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. Accident Analysis & Prevention, 38(1), 185-191. doi: 10.1016/j.aap.2005.09.007

Horrey, Lesch, & Garabet, A. (2008). Assessing the awareness of performance decrements in distracted drivers. Accident Analysis & Prevention, 40(2), 675-682. doi: 10.1016/j.aap.2007.09.004

Stutts, J., Donald, P.D., Reinfurt, W., Staplin, L., Eric, P.D., Rodgman, A., Carolina, B.S., (2001). The role of driver distraction in traffic crashes. AAA Foundation for Traffic Safety.

Jing-Shiarn Wang, R. R. K., Michael J.Goodman. (1996). The role of driver inattention in crashes new statistics from the 1995 crashworthiness data system.

Jonah, B. A., Thiessen, R., & Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. Accident Analysis & Prevention, 33(5), 679-684. doi: http://dx.doi.org/10.1016/S0001-4575(00)00085-3

Kaber, D. B., Liang, Y., Zhang, Y., Rogers, M. L., & Gangakhedkar, S. (2012). Driver performance effects of simultaneous visual and cognitive distraction and adaptation behavior. Transportation Research Part F: Traffic Psychology and Behaviour, 15(5), 491-501. doi: 10.1016/j.trf.2012.05.004

Kircher, K. (2007). Driver distraction: A review of the literature. Swedish Road and Traffic Research Institute.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data.

Lam, L. T. (2002). Distractions and the risk of car crash injury: The effect of drivers' age. doi: http://dx.doi.org/10.1016/S0022-4375(02)00034-8

Lee, J. D. (2007). Technology and teen drivers. J Safety Res, 38(2), 203-213. doi: 10.1016/j.jsr.2007.02.008

Mayhew, D. R., Simpson, H. M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. Accident Analysis & Prevention, 35(5), 683-691. doi: http://dx.doi.org/10.1016/S0001-4575(02)00047-7

McEvoy, S. P., Stevenson, M. R., McCartt, A. T., Woodward, M., Haworth, C., Palamara, P., & Cercarelli, R. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study (Vol. 331).

McKnight, A. J., & McKnight, A. S. (2003). Young novice drivers: careless or clueless? Accident Analysis & Prevention, 35(6), 921-925. doi: http://dx.doi.org/10.1016/S0001-4575(02)00100-8

Neyens, D. M., & Boyle, L. N. (2007). The effect of distractions on the crash types of teenage drivers. Accid Anal Prev, 39(1), 206-212. doi: 10.1016/j.aap.2006.07.004

Neyens, D. M., & Boyle, L. N. (2008). The influence of driver distraction on the severity of injuries sustained by teenage drivers and their passengers. Accident Analysis & Prevention, 40(1), 254-259. doi: http://dx.doi.org/10.1016/j.aap.2007.06.005

National Highway Traffic Safety Administration (NHTSA). (2010). Distracted driving and driver roadway environmental factors.

NHTSA. (2010). Driver Distraction Program.

NHTSA. (2011). Traffic safety facts.

NHTSA. (2013). Visual manual nhtsa driver distraction guidelines for in-vehicle electronic. National Highway Traffic Safety Administration.

National Safety Council (NSC). (2012). Understanding the distracted brain ,why driving while using hands-free cellphone is risky behaviour.

Office of Statistics and Programming. (2011). An analysis of driver inattention using a case-crossover approach on 100-car data. Office of Statistics and Programming, National Center for Injury Prevention and Control.

Olsen, E., Lerner, N., Perel, M., & Simons-Morton, B. (2005). In-car electronic device use among teen drivers. Paper presented at the Transportation Research Board Meeting, Washington, DC.

Patel, J., Ball, D. J., & Jones, H. (2008). Factors influencing subjective ranking of driver distractions. Accident Analysis & Prevention, 40(1), 392-395. doi: 10.1016/j.aap.2007.07.006

Ranney, T. A., Garrott, W.R. & Goodman, M.J. (2001). NHTSA driver distraction research.

Shope, J. T., & Bingham, C. R. (2008). Teen Driving: motor-vehicle crashes and factors that contribute. American Journal of Preventive Medicine, 35(Supplement), S261-S271. doi: http://dx.doi.org/10.1016/j.amepre.2008.06.022

Simons-Morton, B., Lerner, N., & Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers. Accident Analysis & Prevention, 37(6), 973-982. doi: 10.1016/j.aap.2005.04.014

Stevens, A., & Minton, R. (2001). In-vehicle distraction and fatal accidents in England and Wales. Accident Analysis & Prevention, 33(4), 539-545. doi: http://dx.doi.org/10.1016/S0001-4575(00)00068-3

Strayer, D. L., & Drews, F. A. (2004). Profiles in driver distraction: effects of cell phone conversations on younger and older drivers. Human Factors: The Journal of the

Human Factors and Ergonomics Society, 46(4), 640-649. doi: 10.1518/hfes.46.4.640.56806

Strayer, J. M. C., Turrill, Coleman, Medeiros, & Ward, (2013). Measuring cognitive distractions in the automobile.

Stutts, J. C., & Association, A. A. (2001). The role of driver distraction in traffic crashes: AAA Foundation for Traffic Safety Washington, DC.

Westlake, E. J., & Boyle, L. N. (2012). Perceptions of driver distraction among teenage drivers. Transportation Research Part F: Traffic Psychology and Behaviour, 15(6), 644-653. doi: 10.1016/j.trf.2012.06.004

Wheatley, J. B. (2002). Using Driver Performance Measures to Estimate Workload. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Vol. 37. No. 3. SAGE Publications, 1993.

Vita

Ali Mohammadhashemi was born in Tehran, Iran. He is the only son of the family, and he has one sister. He attended National Organization for Development of Exceptional Talents (NODET) High School in Karaj, Iran. After graduation, he attended Iran University of Science and Technology in 2004 and graduated with a bachelor's degree in 2010. After graduation, he started working as an industrial engineer. Seeking to continue his education in the USA, he was admitted in the fall of 2012 to the University of Tennessee, where he accepted a graduate research assistantship. He graduated with a Master's of Science in Industrial Engineering in August 2015.