Spring 2011

Response of novice and experienced drivers to lateral control intervention to prevent lane departures

Nicole Joy Hollopeter
University of Iowa

RESPONSE OF NOVICE AND EXPERIENCED DRIVERS TO LATERAL CONTROL INTERVENTION TO PREVENT LANE DEPARTURES

by

Nicole Joy Hollopeter

A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Industrial Engineering in the Graduate College of The University of Iowa

May 2011

Thesis Supervisor: Associate Professor Geb W. Thomas

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Nicole Joy Hollopeter

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Industrial Engineering at the May 2011 graduation.

Thesis Committee: ___________________________________
Geb W. Thomas, Thesis Supervisor

____
Timothy L. Brown

____
Thomas Schnell

To Mike,
my amazing husband and best friend, this thesis
and degree wouldn’t have been possible without you.
Thank you for being there for and never giving up on me.
I cannot wait to start the next chapter of our lives together.

ACKNOWLEDGEMENTS

This work was completed in conjunction with a larger project on crash warning interfaces funded by the National Highway and Traffic Safety Administration (NHTSA). Appreciation goes to Eric Traube, at NHTSA, Dr. Eric Nadler with Volpe National Transportation Systems Center, and Dr. Neil Lerner with WESTAT for their support of the project.

Special thanks to Tim Brown, who served as a mentor and always made time to listen, provide help, and encourage me. Thanks to Geb Thomas, who was the first to enlighten me, over three years ago, that the ambition of this degree was in fact a possibility, and who has been my guide throughout this journey. Thanks to Dan McGehee for inspiring me and for his many moments of mentorship, expertise, and insight that were crucial in realizing my goals. Thanks to Linda Boyle, who granted me the opportunities that allowed me to be successful. Thanks to Tom Schnell for serving on my committee and always taking the time to share his knowledge with me. Thanks to the National Advanced Driving Simulator and its many individuals who supported, assisted, and collaborated with me on this project. Finally, thanks to the professors, students, and employees at the University of Iowa for offering me such an immense wealth of knowledge, there is no greater gift.

To my family and friends, thank you for your unwavering support, encouragement and love. To my parents, Bruce and Cheri, it is because of you that I am able to succeed in anything I put my mind to. And, to my husband Mike, this thesis is as much yours as it is mine, thank you for being my everything.

ABSTRACT

It is widely known that young drivers are overrepresented in the crash data for reasons such as risk perception and acceptance, age, gender, experience, exposure, and social contexts. The current mitigations implemented to address this issue consist mainly of graduated driver's licenses and parental involvement programs. However, as technology begins to find its way into transportation in the form of advanced driver assistance systems, there is a need to understand whether these technologies will be a benefit or a detriment to young novice drivers. The present study investigates the reactions of young novice drivers to a control intervention lane departure warning. The results show less urgent reactions to the warning from novice drivers compared to their more experienced counterparts. However, no differences in perceptions of the system were found between the novice and experienced groups. Nonetheless, young novice males were found to have degraded performance compared to their novice female peers as well as older more experienced male drivers. This study provides useful insights concerning the necessary investigations of effects of advanced driver assistance systems on young novice drivers and the associated young driver safety epidemic.

TABLE OF CONTENTS

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER 1: INTRODUCTION 1

Magnitude of Young Novice Driver Safety Problem 1
Contributors of the Young Novice Driver Safety Problem 6
Risk Perception and Risk Acceptance 7
Age, Experience, and Exposure 10
Gender 14
Social Contexts 17
Mitigation Methods for the Young Novice Driver Safety Problem 19
Licensing Practices 19
Education and Training 21
Parental Involvement 23
Advanced Driver Assistance Systems and Young Novice Drivers 25

CHAPTER 2: METHODOLOGY 28

Experimental Design 28
Independent Variables 28
Dependent Measures 29
Hypotheses 32
Participants 32
Apparatus 33
Lane Departure Warning System 34
Scenario 36
Roadway Environment 36
Events 38
Distraction Tasks and Controlled Departure 40
Primary Distracter Task 41
Secondary Distracter Tasks 43
Controlled Departure 45
Additional Technologies 46
Speed Violation Warning 47
Trivia Game Alert System 47
Procedures 47
Screening Procedure 47
Briefing 49
Drive 50
Debriefing 51

Data Analysis 52
Removing Events in Which Warning is not Leading Indication of Departure 52
Dealing with Events in Which Driver Departs Opposite the Intended Direction 53
Removing Extreme Outliers 54
Behavioral Effects of Primary Distraction Task 55
Statistical Tests 55

CHAPTER 3: RESULTS 57

Interaction Results 57
Results of Vehicle Based Measures by Condition 60
Initial Steering Response 60
Peak Steer Jerk 61
Steering Reversals 62
Results of Subjective Measures 63

CHAPTER 4: DISCUSSION 65

Hypothesis 1 65
Hypothesis 2 66
Hypothesis 3 67
Limitations & Future Work 68
Conclusions 70

APPENDIX A: POST DRIVE QUESTIONNAIRE 72

APPENDIX B: SCENARIO MAP 75

APPENDIX C: BUG TASK SPECIFICATIONS 76

APPENDIX D: CD & TRIVIA TASKS SPECIFICACTIONS 79

APPENDIX E: EMAIL WORDING 81

APPENDIX F: PHONE SCREENING 82

APPENDIX G: INFORMED CONSENT 88

APPENDIX H: NADS DRIVING HISTORY QUESTIONNAIRE 95

APPENDIX I: TRAINING PRESENTATION 103

APPENDIX J: IN-CAB PROTOCOL 109

APPENDIX K: DEBRIEF STATEMENT 110

APPENDIX L: SAMPLE PLOT OF EVENT 111

REFERENCES 112

LIST OF TABLES

Table 1: Teenage Motor Vehicle Crash Deaths.. 2

Table 2: Risk of Passengers 18

Table 3: Vehicle Based Dependent Measures 30

Table 4: Subjective Dependent Measures 31

Table 5: Hypotheses 32

Table 6: SCC_Lane_Deviation Cell Specification 36

Table 7: Trivia Game Event Order and Description 43

Table 8: CD Task Event Order and Description 44

Table 9: Summary Table of Vehicle Based Results 57

Table 10: Summary Table of Subjective Results 63

Table C1: Bug Task Specifications 76

Table D1: CD Task Specifications 79

Table D2: Trivia Task Specifications 80

LIST OF FIGURES

Figure 1: Cause of Death in 2000, Ages 15-19 3

Figure 2: Proportion of Youth in Driver Fatalities and Population 5

Figure 3: Road User Fatalities per Million Population, by Gender and Age 15

Figure 4: Experimental Design 28

Figure 5: NADS-1 Driving Simulator (left) with a Driving Scene from Inside the Dome (right) 33

Figure 6: Conceptual Description of Roadway Database 37

Figure 7: Curve Geometry Decomposition 38

Figure 8: Bug Catch Task 42

Figure 9: Trivia Game Touch Screen Interface 44

Figure 10: Proportional Controller Used to Create Steering Input 45

Figure 11: Predicted Lateral Acceleration for Subtraction from Motion Cue 46

Figure 12: Standard Deviation of Lane Position Interaction 59

Figure 13: Maximum Lane Exceedance Interaction 60

Figure 14: Initial Steering Response after the Warning by Condition 61

Figure 15: Peak Steering Jerk of Event by Condition 61

Figure 16: Number of Steering Reversals by Condition 62

Figure 17: Driver Perception of the Timing of the Warning 64

Figure A1: Post Drive Subjective Questionnaire 72

Figure B1: Scenario 1 Map of Events 75

Figure E1: Email Advertisement Wording 81

Figure F1: Phone Screening Procedures 82

Figure G1: Informed Consent for 16-17 Year Old Participants 88

Figure H1: NADS Driving History Questionnaire (Teens) 95

Figure I1: Training Presentation 103

Figure J1: In-Cab Protocol 109

Figure K1: Debrief Statement 110

Figure L1: Sample Plot of Curve Event Showing Local
Lateral Ay of -0.1 111

CHAPTER 1: INTRODUCTION

Magnitude of Young Novice Driver Safety Problem

It is widely known that young drivers are vastly over represented in motor vehicle crash rates. For years, teenage drivers as an age group have been considered to pose the greatest risk to themselves and other road users and are more likely to be injured or killed in a motor vehicle accident than their more experienced counterparts (Ferguson et al., 1996; Mayhew, Simpson & Pak, 2003; McCartt et al., 2009; Rivara, 1982; Jonah et al., 2001; Mayhew et al., 1986). This issue has become a great concern to the degree that the National Institute of Child Health and Human Development (NICHD), the National Highway Traffic Safety Administration (NHTSA), and the National Center for Injury Prevention of the Centers for Disease Control and Prevention (CDC) assisted in organizing an expert conference on the topic in 2002 (Simons-Morton, 2002).

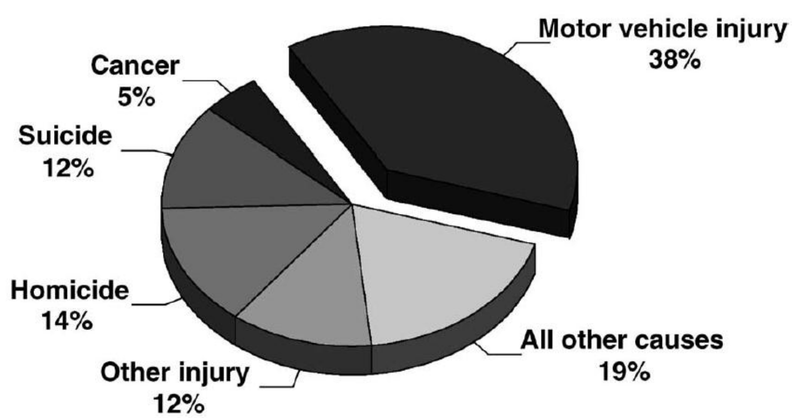
According to the Insurance Institute for Highway Safety, teenagers accounted for 12 percent of all passenger vehicle crash deaths and represented 10 percent of the total deaths from all motor vehicle crashes in 2009 (see Table 1). This representation left 3,466 teenagers dead as a result of a motor vehicle crash within the span of a year, accounting for a staggering 33 percent of all deaths among 13-19 year olds (Insurance Institute for Highway Safety, 2009). As a representation of the vast number of young lives that motor vehicle crashes are responsible for ending, if one were to calculate the number of years of life lost, motor vehicle crashes rank third overall. That is to say that motor vehicle crashes are the third highest consumer of years a person would have been expected to live had they not died, ranking just behind cancer and heart disease (Subramanian, 2006).

Table 1: Teenage Motor Vehicle Crash Deaths

Death type	Teen crash deaths	Crash deaths for all ages	% teen crash deaths of all crash deaths
Passenger vehicle occupant	2,872	23,437	12
Pedestrian	256	4,092	6
Motorcyclist	134	4,281	3
Bicyclist	66	630	10
All-terrain vehicle riders	70	336	21
Other	68	1,032	7
Total	3,466	33,808	10

Represented as percent of all motor vehicle crash deaths, 2009
Source: Insurance Institute for Highway Safety 2009

These overwhelming numbers are not isolated to the present. For example, in 2002 and 2003 driving was the leading cause of death among those between the ages of 4 and 34 (Subramanian, 2006; Subramanian, 2005). Furthermore, in 2000 motor vehicle injuries were the cause of 38 percent of deaths of those between the ages of 15 and 19 years (see Figure 1), (Foss & Goodwin, 2003). Over a decade ago, in 1995, 16, 17 and 18 year old drivers combined were involved in four times as many crashes as drivers aged 35-55 (Williams, 2003). Looking even further back in time, in 1978 the number of motor vehicle related deaths of drivers aged 16 to 17 years was a astounding 4,198, which accounted for nearly half of all deaths of 16-19 year olds in the United States (Karph & Williams, 1983). In 1963, young drivers had a death rate that was twice that of drivers aged 35-55 years (Schuman et al., 1967). An even deeper look shows that this epidemic has been going on for almost a century. Since the 1930s, motor vehicle mortality rates for 15-24 year olds have risen faster than any other 10 year age bracket. And, since 1916 (just 28 years after the first automobile was sold) mortality for the under 15 age group has had a distinctly different pattern than that of all ages combine (Markush et al., 1968).



Source: Foss & Goodwin, 2003

Figure 1: Cause of Death in 2000, Ages 15-19

However this prevalence is not isolated to the United States, according to the World Health Organization, similar numbers are seen for more than 30 European regions (Waldeyer & Gapp, 2009). Moreover, the World Health Organizations reported that motor vehicle fatalities for individuals 15 to 19 years of age saw on overall increase from 1950 to 1970. (Harvard, 1979). In Australia, 16-24 year olds compromised about 20 percent of the driving population in the early 1990s, but accounted for about 35 percent of fatal and 50 percent of injury related motor vehicle crashes (Catchpole, Macdonald & Bowland, 1994; Macdonald, 1994). This skewed ratio is common among many developed countries, the Organization for Economic Co-Operation and Development (OECD) and the European Conference of Ministers of Transport (ECMT) published a report on the young driver safety problem and noted that while individuals under the age of 25 make up only about one tenth of the population in OECD countries, they represent more than a quarter of drivers killed on the road (see Figure 2). This translates to over 8,500 young driver deaths in the 30 OECD countries (including the US) each year (OECD, 2006).

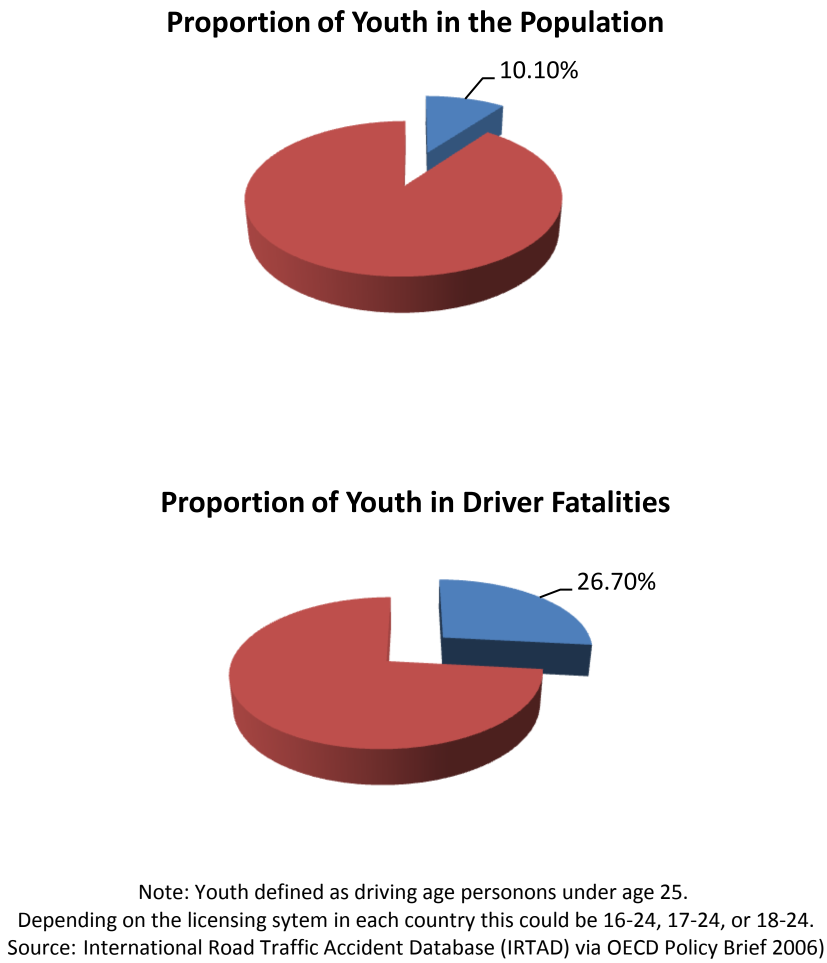


Figure 2: Proportion of Youth in Driver Fatalities and Population

From 1997-2001 the young driver injury rates in Australia significantly increased by an average of 12 percent per year (Chen et al., 2010). In Canada, drivers aged 16-19 are three to four times more likely to be involved in a crash than drivers in their 40's (Stewart & Sanderson, 1984). Furthermore, according to the Ontario Road Safety 2007 Annual Report, individuals between the ages of 16 and 20 were responsible for thirty percent of all fatalities associated with motor vehicle crashes in Ontario Canada in 2007 (Ontario Ministry of Transportation, Ontario Road Safety Annual Report [ORSAR], 2007).

A common criticism of the unproportional motor vehicle deaths for young novice drivers is the idea that their over representation is due to the unproportionally low number of miles driven by young novices. However, the issue remains present after controlling for exposure. In the United States, although teenagers drive less than all but the oldest individuals, their numbers for crashes and crash deaths remain disproportionately high when viewed on a per mile basis (Insurance Institute for Highway Safety, 2009). In 1990, 16 year olds had 43 crashes per million miles driven compared to a mere 5 crashes per million miles driven for drivers 25 years of age and older (Ulmer, Williams & Preusser, 1997). Moreover, based on miles driven in 1990, teenagers had three times the risk of being in a fatal crash compared to all drivers (Massie, Campbell & Williams, 1995). When they controlled for the exposure, McKnight and McKnight (2003) found that drivers 16 years of age are 10 times more likely to be in a severe crash than adult drivers.

Contributors of the Young Novice Driver Safety Problem

The question: 'what are the primary contributors to the sizeable young novice driver safety problem?' has been examined in a multitude of ways resulting in an assortment of answers. There are many things that contribute to driver safety, from highway and vehicle design to driver distraction. Some of the most prevalently discussed contributors of the young driver population are associated with the risk levels, age, experience, exposure, gender, and social contexts of young novice drivers.

Risk Perception and Risk Acceptance

One factor commonly studied as a contributor to the young driver safety problem is the perception and acceptance of risk. McKnight and McKnight (2003) noted that most non-fatal accidents appear to result from a

> "failure to employ routine safe operating practices
> and failure to recognize the danger in doing so."

Catchpole, MacDonald and Bowland (1994) concluded that higher crash rates seen for young drivers are owed not to their age or gender, but to their willingness to take risks and their lower skill levels. Furthermore, Waller et al. (2001) speculated that young drivers lack the ability to recognize the risks involved in driving behaviors, and concluded that as experience is gained, young drivers will begin to recognize these risks and become reluctant to engage in such behaviors. Finally, Mao et al. (1997) found that the factors related to crash involvement were generally associated with risk taking behaviors.

Young drivers are, in general, more willing to accept risks or adopt risky driving practices and have a tendency to take more risks in their every day driving (Deery, 1999; Mao et al., 1997; Evans & Wasielewski, 1983; Wasielewski, 1984). For example, a study by Evans and Wasielewski (1983) showed that young drivers leave shorter distances to the car in front of them than older drivers. Bottom and Ashworth (1978) found that young drivers are willing to accept narrower gaps when entering traffic than older drivers. Koneci, Ebbesen & Koneci (1976) found that when faced with a yellow light at an intermediate distance, young drivers were more likely to proceed through the intersection than older drivers, causing them to have a higher likelihood of violating a red light than older drivers. Furthermore, young novice drivers accept higher speeds than older drivers (Wasielewski, 1984; Aarts & Schagen, 2006; Harrington & McBride, 1970) and only 18 percent of adolescents report using a seatbelt consistently (Litt & Steinerman, 1981). Overall, drivers who take the most risk tend to be the youngest (Quimby, 1988).

These findings are evidence toward young driver's higher levels of risk acceptance and associated skewed perceptions of risk. Risk acceptance is defined as the amount of risk a driver is willing to tolerate and is a subjective value selected by the driver himself (Bloomquist, 1986; Deery, 1999; Janssen & Tenkink, 1988; Wilde, 1986). In other words, due to the self-paced nature of driving, the driver chooses the acceptance threshold he is willing to tolerate. Once this threshold is set, the driver must determine if an action or hazard is above or below this threshold based on the perceived amount of risk associated with that particular action or hazard. Thus, the acceptance threshold is based heavily upon the level of risk the driver perceives (Stein & Allen, 1987).

Risk perception refers to the subjective assessment of risk in potential traffic hazards and is believed to play an important role in driver safety (Brown & Groeger, 1988; Gregersen, 1996). A literature review by Deery (1999) revealed that a person's perception of risk in a traffic hazard can be used to predict their driving record and that the level of risk that drivers perceive is inversely related to their crash record. Quimby (1988) conducted a study that also found subjects' perceptions of risk to be negatively correlated with their accident history, and concluded that drivers with risky every-day driving styles perceive low levels of risk. Risk perceptions are said to be determined by two inputs: information regarding the potential hazards in the traffic environment and the information about the ability of the driver (& capabilities of the vehicle) to prevent the potential hazards from being transformed into an accident or crash (Brown & Groeger, 1988).

The first input is related to the process of identifying hazardous situations and quantifying the threat potential of such situations. In general, novice drivers are less able to assess risk in traffic hazards than older drivers (OECD, 2006). Research has shown that young driver's detection of hazards is slower, less efficient, and less holistic than experienced drivers (Fisher, 2006; Deery, 1999).

The second input relates to information about the driver's ability to prevent a potential hazard from becoming an accident. This subjective assessment is made solely by the driver and plays an important role in the driver's risk perception. The driver's assessment of their capability of handing an event drives the extent to which the event is assessed as hazardous. Young novice drivers perceive themselves as more skillful than the average driver and consistently estimate their personal risk to be lower than their peers (Engstrom et al., 2003; Deery, 1999).

Overall, young novice road users are more risky drivers than older road users. However as Deery (1999) points out, the risky driving styles of novice drivers may not always be deliberate, and may be associated with their age and inexperience.

Age, Experience, and Exposure

While driver age, experience, and exposure can be considered related, their exact relationship, has created some controversy in the literature. In an attempt to determine the relative contributions of age and experience to the young driver safety problem, several studies have attempted to separately quantify their contributions. It is evident that drivers of young ages are overrepresented in the crash data, but to what extent is their representation due to their age alone and to what extent is it due to their lack of experience? For a teenager, the experience gained in one month's time has a profound effect on their crash rate. The crash rate of a teenager drops from 5.9 per 100 licensed teens the first month to 3.4 the second month (McCartt, Shabanoca & Leaf, 2003). In an attempt to gain an understanding of the age/experience relationship, Mayhew, Simpson and Pak (2003) conducted a study of over 40,000 novice drivers of all ages over a 24 month period and examined month to month changes in collisions. A clear age effect was found, as teenage novice drivers had higher crash rates than older novice drivers at each month of driving experience. Moreover, during the first month of licensure, young novice driver had a crash rate that was twice that of their older novice counterparts.

Vlakveld (2004) conducted a similar study in the Netherlands and found that the younger the age at licensure the higher the risk of a crash during the first year of licensure. In 1992, Simpson and Mayhew examined collision rate as a function of age and years of licensure and found that decreased crash rates were strongly associated with increasing age. Controlling for years of licensure, the collision rate for a 16 year old was double the collision rate of a 25 year old and almost four times that of a driver 51 years of age or older.

Cooper, Pinili and Chen (1995) also investigated the relationship between age and experience by controlling for experience during the first three years of licensure among drivers ages 16-55. Again, independent beneficial age effects were found. Interestingly, this study also explored the at-fault and non-fault aspects of the crash data and noted that the beneficial age effects were stronger for at-fault crashes. Drivers aged 16-19 had almost twice as many at-fault crashes than non-fault crashes, a ratio that was not common for their older counterparts. The authors concluded that the overall higher crash rates of young novice drivers are propelled by their higher at-fault crash rates. However, the authors also identified a lack of experience, defined as a combination of short licensure time and low exposure to travel, as a controlling factor in reducing at-fault crash rates for novice drivers.

When the relationship of both age and experience to the young driver safety problem is examined, there are generally beneficial effects of age that surface along with some side effects of inexperience (Laberge-Nadeau, Maag Bourbeau, 1992; McCartt et al., 2009; McCartt, Shabanova & Leaf, 2003). However, the age of an individual has also proven to be related to the amount of driving they may do on an annual basis. Drivers of the youngest and oldest ages tend to drive fewer miles per year than the average road user. From 2001-2002, 16 year old drivers drove an average of approximately 7,000 miles while drivers 25-54 year of age averaged about 17,000 miles (Ferguson, Teoh & McCartt, 2007). When crash rates are given per mile driven, crash risk can be measured based on comparable amounts of exposure (Williams, 2003). Accounting for such exposure helps clarify the differences seen in age. Ferguson, Teoh and McCartt (2007) found that for every 100 million miles traveled, fatal crashes were highest for drivers aged 16-19 years old (and drivers above the age of 85), and lowest for drivers between 30 and 60 years of age. Accounting for exposure also helps clarify the differences seen in experience. In 2003, McCartt, Shabanova & Leaf found that crash rates for teen drivers per 10,000 miles driven was 3.2 during the first 250 miles driven and dropped to 1.8 and 1.3 for the second and third 250 mile increments respectively and continued to decline.

Experience and age have both proven to be factors of the young driver safety problem, and while there is evidence that age is the stronger effect, their relationship with respect to exposure needs clarification. It is for this reason that studies have attempted to evaluate age and experience independently while also controlling for exposure.

By controlling for exposure, Maycock, Lockwood and Lester (1991) found that the reduction in crash risk was greater after the first year of experience than it was after one year of age. Moreover, for 17-25 year old drivers, the effect of eight years of experience was greater than the effect of eight years of age. However, the study also showed that the decline in crash risk as experience increased was greater for younger drivers than older drivers, indicating that experience has a greater effect on younger drivers.

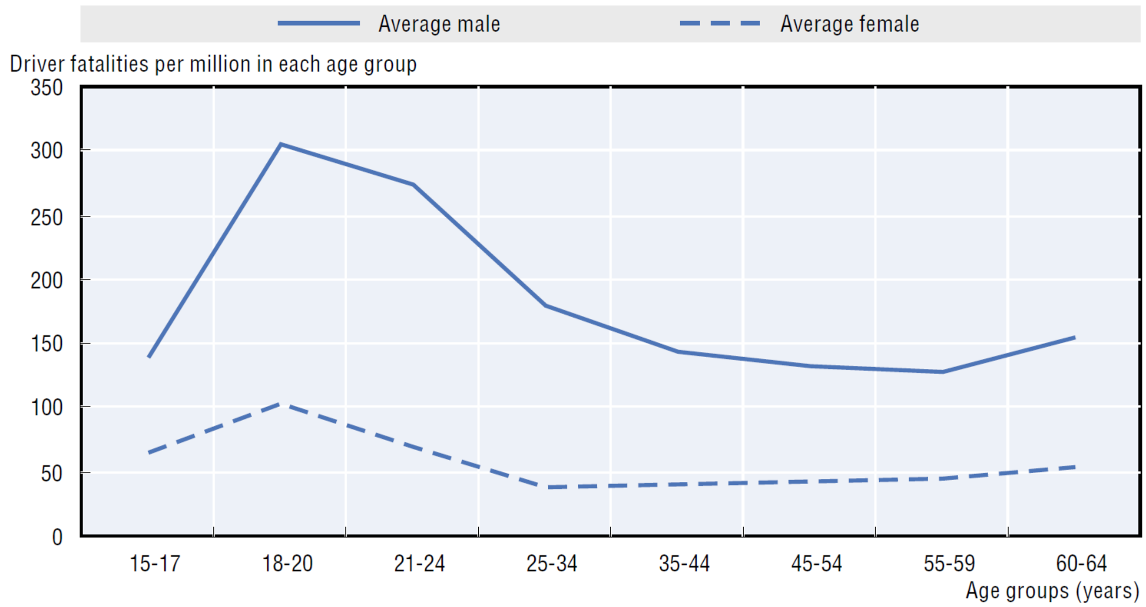
In 1995, Forsyth, Maycock and Sexton also found that, when controlling for exposure, the effect experience had on crash rates was greater than that seen by the effect of age. The study of United Kingdom drivers used a Generalized Linear Model to explore the relationship between age, experience, and exposure on accident liability (number of accidents per year).

The study showed that when accident liability arising from additional years of age and driving experience (as a function of age) were evaluated for drivers licensed at the age of 17 (initial licensing age in the UK), a 38 percent reduction in crash risk after the first year of licensure was found, compared to a 9 percent reduction in crash risk as an effect of one year of age. Again, suggesting that when exposure is controlled, experience has a greater effect on young novice driver crash rates than age.

Overall, there are effects of both age and experience on the young driver safety problem and it's clear that even after controlling for exposure, age and experience have independent as well as relational effects on crash risk (McCartt et al., 2009; Peltz & Schuman, 1971).

Gender

Gender also plays a role in the young driver safety problem. In terms of magnitude, males are the most frequently represented in the crash data (Massie, Campbell & Williams, 1995; Twisk & Stacey, 2007). Over the span of a decade, from 1997 to 2007, male drivers comprised 51 percent of licensed drivers in Australia, but represented over 78 percent of motor vehicle fatalities (Chen et al., 2010).



Source: International Road Traffic Accident Database (IRTAD) via OECD 2006,

Figure 3: Road User Fatalities per Million Population, by Gender and Age

When examining the interaction between age and gender, studies have shown that regardless of age male drivers are involved in more crashes than female drivers (see Figure 3) (Maycock et al., 1991; Laberge-Nadeau et al., 1992; McKenna et al., 1998). For example, Massie, Campbell and Williams (1995) found the differential of risk of fatal crashes between males and females to be age independent. By combining travel data with crash data, they found that male drivers had up to 2.5 times the risk of being involved in a fatal crash than females of the same age group. It should be noted, however, that some researchers have found that the difference in risk of crash involvement between male and female drivers has proven to diminish with age. Massie, Campbell and Williams (1995) found that for drivers over

60 years of age, there is essentially no difference in crash risk between male and female drivers.

Yet, age does have an effect within gender groups that is significantly stronger for male drivers than for female drivers (Laapotti et al., 2001). Regardless of experience, collision rates are substantially higher for young male drivers than for older male drivers (Laberge-Nadeau et al., 1992). In the US, motor vehicle death rates are at more than twice as high for young men as for older men (Schuman et al., 1967).

In general, young male drivers tend to take more risks in their everyday driving. This is apparent with shorter headways, higher crash rates, more offenses, and higher speeds (Evans & Wasielewski, 1983; Maycock et al., 1991; Laapotti et al., 2001; Laberge-Nadeau et al., 1992; McKenna et al., 1998). Moreover, young male drivers are often persistent offenders (Laapotti et al., 2001). And, although it has been shown that young males drive worse than their female peers and older male counterparts, they perceive their driving to be better than their peers and just as good as older male drivers (Groeger & Brown, 1989). As previously noted, such subjective assessments from the driver are an important input in to the driver's risk perception and acceptance. Consequently, compared to their female counterparts, crashes involving young males are almost twice as likely to be fatal as those involving young female drivers (Mao et al., 1997).

Overall, there seem to be significant difference between young male drivers and their older male and young female counterparts.

Social Contexts

The presence of a passenger in the vehicle of a teen driver creates a social system that can have both positive and negative effects on their likelihood of a crash. Interestingly, the likelihood of a crash is increased by the presence of another teenage passenger while an adult passenger can potentially decrease the likelihood of a crash (Williams, 2003). In fact, accident rates are nearly twice as high when teenage passengers are present and over half of deaths associated with 16-17 year old drivers occur when a passenger younger than 20 years is in the vehicle (Gregersen & Bjurulf, 1996; Williams, 2003; Insurance Institute for Highway Safety, 2009). This increase in risk associated with the presence of teenage passengers has also proven to be related to the gender of the passenger. Simmons-Morton et al. (2005) found that with a male teenage passenger present, teenage drivers showed higher rates of speeding and one-fourth of teenage drivers exceeded the speed limit by at least 15 mph (compared to less than 10 percent of general traffic). Moreover, there is a direct relationship between number of passengers and risk of a crash; as the number of passengers increases, so does the risk. Chen et al. (2000) found that three or more passengers dramatically increased the risk of death for 16 and 17 year olds (see Table 2) and Williams (2003) found that the increase was four times that of driving alone.

Table 2: Risk of Passengers

Driver Age	Number of Passengers	Risk of death per 10 million trips*
16	1	1.39
16	2	1.86
16	3+	2.82
17	1	1.48
17	2	2.58
17	3+	3.07

*Compared to drivers of the same age with 0 passengers.
Source: Chen et al., 2000.

Technology also plays a role in the social contexts of young drivers. Young drivers are more willing to accept new technologies and devices, and generally use them in conjunction with social networking. This early and quick adoption of technologies and desire to stay connected with peers, combine with skewed perceptions of their driving and multi-tasking skills, can have a negative effect on young novices' driving. Sarkar & Andreas (2004) note that as drivers gain confidence with new technologies they over estimate their abilities to interact with them while driving. This is often manifested in the form of distracted driving, which is responsible for over 24 percent of crashes of 16-19 year drivers (Neyens & Boyle, 2008). There is a large body of literature on teenage driver distraction that provides the general understanding that distracted driving increases the likelihood and severity of a crash (Young & Regan, 2007).

Mitigation Methods for the Young Novice Driver

Safety Problem

Methods for reducing the severity of the young novice driver safety problem vary from stricter legislation policies to simply encouraging better parenting skills (Gillian, 2006; OECD, 2006; Williams, 2005; Simons-Morton et al., 2006; Mayhew & Simpson, 2002; Senserrik, 2007; Simmons-Morton, 2007; Haggerty et al., 2006). In particular, changes to licensing practices, updates to existing and implementation of new driver education and training programs, and employment of parental involvement strategies are the commonly researched and evaluated mitigation methods.

Licensing Practices

The young driver safety problem has clearly proven to have an association with age (Twisk & Stacey, 2007; Williams & Ferguson, 2002). Thus, it would seem logical to increase the required full licensure age in order to decrease the crash rate. Increasing the licensure age has been shown as an effective policy for mitigating crashes (Williams, 2006; Williams, Karpf & Zador, 1983). However, the implications for mobility, social, and lifestyle sacrifices have been factors preventing such changes in licensure policies (Williams, 2005). Furthermore, delaying the licensure age alone does not address the factor of inexperience (Ferguson et al., 1996).

Regardless of age at licensure, it is widely opined that simply passing the driving test and gaining the ability to drive solo should not be the final step in the process of acquiring licensure, as it exposes novice drivers to risks they are not yet able to manage (Hedlund & Compton, 2004; Gillian, 2006; Twisk & Stacey, 2007; McCartt et al., 2009; Foss & Evenson, 1999). As previously noted, experience with managing such risks has proven to be a factor in improving the overall driving performance of young novice drivers. However, this is where the literature forms a paradox: increased exposure leads to increased risk, however inexperience can only be overcome through increased exposure. It is for this reason that many states, and countries for that matter, are moving from a uni-phased licensing system to a multi-phased, or graduated, licensing system. Forms of Graduated Drivers' Licenses were implemented irregularly from 1979 to the mid 1990s and are currently adopted by over two thirds of states in the US (Simons-Morgan, 2002).

The idea behind graduated licenses is the untangling of the "licensure paradox" through phases that allow young drivers to gain experience only under conditions of minimal risk (Simpson & Mayhew, 1987; Hedlund & Compton, 2004; Ferguson, 2003; McCartt, 2009). Generally, the primary elements of a graduated license require a minimum learning period in which there are combinations of the following: controlled nighttime driving, passenger restrictions, extended periods of supervised practice driving, and demerit alcohol and citation systems (Shope & Molnar, 2003; Foss, Feaganes & Rodgman, 2001; Hedlund, 2007). However, because graduated license programs are not all the same, it is the concept of the system that is important. Foss and Evenson (1999) best define the requirement for a system to be considered a graduated licensing program,

> "…the critical issue is not how many stages exist, nor which limitations are in place. Rather, the question is whether a licensing system is designed in such a way that the novice driver progress from less to more risky driving conditions as they obtain required experience and that they are required to demonstrate appropriately safe driving behavior to progress (i.e., graduate) from one level to the next."

Graduated licensure programs have proven to be a significant step in the right direction for helping young drivers further develop their abilities before being exposed to risks they are not yet able to manage (Foss, Feaganes & Rodgman, 2001; Williams, 2005; Shope & Molnar, 2003; Simpson, 2003). However, many authors note that there is insufficient data to accurately assess their effectiveness (Williams & Ferguson, 2002; Foss & Evenson, 1999; Ferguson, 2003; Shope, 2006). Nevertheless, this mitigation method is cited in much of the literature as the best potential solution available to the current young driver safety issue (Williams & Ferguson, 2002; Senserrick, 2006; Gillan, 2006; Williams, 2006).

<u>Education and Training</u>

Driver education was initially available through the public school system in the United States in the 1950s and has, for the most part, remained readily available to young pre-drivers (Lonero, 2008; Simmons-Morton & Ouimet, 2006). The standard formal driver education in the United States has not been proven to be an effective method for reducing the risk of young drivers (Christine, 2001; Mayhew et al., 1998; Vernick et al., 1999; Williams & Ferguson, 2004; Mayhew et al., 2006; Simons-Morton, 2002; Williams, 2006; Mayhew & Simpson, 2002). This is primarily due to the limited amount of in-vehicle training involved and the focus on high level maneuvering and basic vehicle skills such as lane change procedures and turn signal usage (Mayhew & Simpson, 2002; Lorno, 2008; Williams & Ferguson, 2004). Most driver education programs only include about 30 hours of classroom training and 6 hours of in-vehicle instruction (Williams & Ferguson, 2004).

However, driver education in its present state does provide an infrastructure that can be revolutionized and utilized to address the young driver safety problem (Williams & Ferguson, 2004; Simons-Morton, 2002). By developing current driver education programs into training programs that focus on perception, anticipation, avoidance of risk, calibration and self assessment skills, and hazard perception, the crash rate of young drivers can potentially be reduced (Kuiken & Twisk, 2001; Simons-Morton, 2002; Fisher, Pollatesek & Pradhan, 2006). Several European countries have begun to capitalize on such training programs by implementing advanced, or second phase, programs after full licensure is awarded. With a focus on methods for dealing with specific situations rather than vehicle skills, these programs have seen improvements to the overall crash rate of young novice drivers (Shope & Molnar, 2003; Williams, 2006; Twisk & Stacey, 2007; Senserrick, 2007).

Parental Involvement

The level of involvement parents elect to assert during the learning stages of driving has a large effect on their teen drivers. What age teens get their license, when and how often they are allowed to drive, who they are allowed to drive with, how they learn to drive, and the monitoring and regulations associated with these restrictions are controlled in large part by the parents (McCartt, Hellinga & Haire, 2007; Simons-Morton, Ouimet & Catalano, 2008; Beck et al., 2003; Simons-Morton & Hartos, 2003). Such control is promoted by insurance agencies, highway safety programs, and government. A review of the literature shows that good parent management with respect to teen driving is associated with lower levels of risking driving behavior, less citations, and fewer crashes (Hartos, Eitel & Simons-Morton, 2002; Hartos, Eitel & Simons-Morton, 2001; McCartt et al., 2003; Simons-Morton et al., 2006).

In the United States, many states have increased the amount of supervised driving required for licensure, with some states requiring as much as 50 hours (Simons-Morton, 2007). This requirement is sometimes in conjunction with a graduated drivers licensing program, and has proven to be a vital asset to the program overall (McCartt, Hellinga & Haire, 2007; Williams & Ferguson, 2002; Foss & Goodwin, 2003; Shope & Molnar, 2003).

Limit setting is also an area in which parental involvement has positive implication on teen driver crash rates (Simons-Morton & Ouimet, 2006). Studies have shown that parents who invoke strict limits on the presence and number of teen passengers and occurrence of nighttime driving reduce their young driver's overall risk (Hartos, Eitel & Simons-Morton, 2002; Hartos, Eitel & Simons-Morton, 2001; McCartt et al., 2003; Simons-Morton et al., 2006). Multiple methods to encourage limit setting have been developed and proven to have positive effects on the young driver safety issue. The Checkpoint Program developed by Simons-Morton, Hartos and Beck (2004) provided parents with an agreement, or contract, that was negotiated with their teen driver in order to encourage limit setting. Haggerty et al. (2006) studied the effect of home visits to encourage development of driving rules and adaptations of written contracts for limit setting. Both programs found positive results with respect to reduced crash risk (Simmons-Morton, Harthos & Beck, 2004; Haggerty et al., 2006).

Parents are beginning to feel empowered by programs such as the graduated driver's license and checkpoint systems, and new technologies are beginning to play a role in assisting parents in successful supervision and enforcement. In a survey by McCartt, Hellinga and Haire (2007) almost all parents stated that they plan to supervise their teenagers driving in some way. Devices such as cell phone GPS systems, data recording computer chips, and video cameras can be placed in a teenager's vehicle to extend parent supervision. McGehee et al. (2007) utilized an event triggered video camera in conjunction with weekly parental feedback to not only assist parents in the supervision of their teen drivers, but also provide contextual teachable moments to aid parents in safe driving instruction. Results from the study showed that within the first nine weeks of intervention, the number of safety related "events" was reduced by 58 percent.

However, there is concern about parent's willingness to *invade* their teen's privacy with surveillance technologies. McCartt, Hellinga & Haire (2007) found that on average about 32 percent of parents said they would consider using a video camera and 50 percent said they would consider data recording chips or cell phone GPS devices as surveillance mechanisms. While further research is needed on the implementation of new technologies to assist in parental supervision and instruction, the preliminary findings seem to show that they have the potential to significantly reduce the number of teens killed in motor vehicle crashes and are complementary to graduated licensing programs (McGehee et al., 2007; Brovold et al., 2007).

Advanced Driver Assistance Systems and Young Novice Drivers

Advanced driver assistance systems (ADAS) are vehicle based technologies designed to assist the driver with the driving task. Much like a stick pusher that automatically compensates for human error in an aircraft, ADAS are designed and intended to support the driver and protect against human error in a vehicle. ADAS have been evaluated with general populations over the last two decades and have proven beneficial in decreasing crash risk (Brown, 1994; V.A.W.J. Marchau, 2005). However, while much of the recent literature briefly notes the need for further exploration of ADAS or collision avoidance systems (CAS) and their effects on the young driver safety issue, currently an experiment has yet to include young novice drivers as a specific age group (Braitman et al., 2008; Twisk & Stacey, 2007; Hedlund, 2007; Lee 2007).

It has been speculated that ADAS can reduce the impact of poor driving skills and, in conjunction with graduated licensing and training programs, have the potential to make driving safer for young and novice drivers (Hedlund, 2007; Senserrick, 2006; Lee, 2007). Braitman et al. (2008) found that run off road was the most common collision type for teens and speculates that Electronic Stability Control (ESC) and Lane Departure Warning Systems (LDWS) may be effective in preventing crashes. However, the author also notes that because these systems have not yet been evaluated with teens, there is no direct evidence to support such a speculation (Braitman et al., 2008). Moreover, Lee (2007) suggests that using ACWS in conjunction with GDL by tailoring ACWS to the needs of young drivers may mimic the benefits seen from an adult supervisory passenger. However, the potential for these technologies to be a detriment to young drivers has also been considered, and thus there is a need for young novice specific research of ACWS (Twisk & Stacey, 2007; Lee, 2007).

CHAPTER 2: METHODOLOGY

Experimental Design

The experiment is a factorial design with 3 factors: Driver Experience, Gender, and Lane Departure Event. Figure 4 shows the experimental design below.

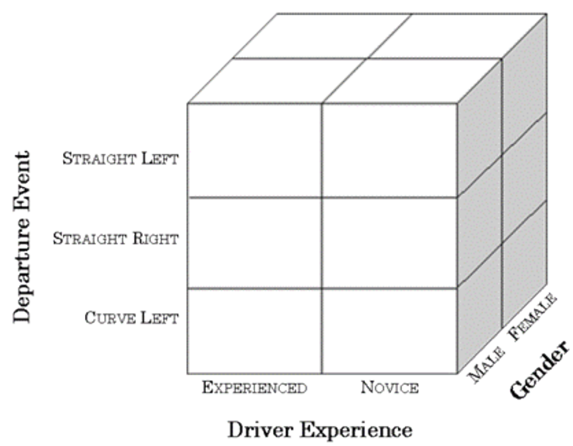


Figure 4: Experimental Design

Independent Variables

Driver experience is a between subject variable with two conditions:

1. Adult
2. Novice

Lane departure event is a within subject variable with three conditions:

1. Drift off road to right
2. Fail to track left curve
3. Drift across centerline, with approaching traffic

Dependent Measures

A multitude of dependent measures were gathered during and after the simulator drive. These measures were either vehicle based measures or subjective measures and are detailed below.

Vehicle-Based Measures

Vehicle-based measures are generally inputs or reactions from the driver and illustrate how the driver responded to the LDW and how the LDW effected driving performance. Among these are measures are steering wheel inputs, accelerator and brake pedal inputs, and vehicle states and associated lane positioning. Table 3 lists the vehicle-based measures collected and gives a brief description of each.

Subjective Measures

Questionnaires administered both before and after the participants' experience with the LDW system were used to gather the subjective measures. These measures describe participants' opinions about the LDW system and their opinions about their driving performance related to the

LDW system. The subjective dependent measures are described in Table 4 and the post drive questionnaire can be found in Appendix A.

Table 3: Vehicle Based Dependent Measures

		Measure	Description	Units
Vehicle Based Measures	Behavioral Response	Time to Accelerator Release	Time from the start of the lane departure until the driver begins to release the accelerator release prior to the full release of the accelerator	seconds
		Time to Initial Steering Response	Time from the start of the lane departure until the driver begins to provide steering input to correct the lane departure	seconds
		Magnitude of Initial Steering Response	The absolute value of the steering wheel angle for the initial steering response after lane departure	degrees
		Number of Steering Reversals	The number of times the driver reverses steering directions after the initial steering response	count
		Peak Steering Rate	peak steering rate magnitude from initial steering response to stabilization in lane	degrees per second
		Peak Steering Jerk	peak steering jerk magnitude from initial steering response to stabilization in lane	degrees per second squared
	Performance	Standard Deviation of Lane Position	The standard deviation of the lane position of the vehicle relative to the center of the lane from initial steering response to stabilization in lane	centimeters
		Maximum Extent of Lane Exceedance	The maximum lateral distance that the leading edge of the vehicle extends out of the lane from initial steering response to stabilization in lane	meters
		Duration of Lane Exceedance	The total amount of time that part of the vehicle is out of the lane from initial steering response to stabilization in lane	seconds
		Lane Exceedance Exposure (Area)	A composite measure that takes into account both the lateral and longitudinal distances that the vehicle is past the warning point from initial steering response to stabilization in lane	meters squared
		Change in Velocity	The total change in velocity of the vehicle from the start of the lane departure until the driver has resumed normal lane keeping	meters per second
		Run-off road	Driver's vehicle fully departs the road (Binary)	binary

Table 4: Subjective Dependent Measures

Subjective Measures	Catch Attention	The alert... Did not catch my attention (1)- Caught my attention (7)
	Distracting	Alert was... Not Distracting (1) - Distracting (7)
	Feeling	Ability to feel the alert Very Difficult (1) - Very Easy (7)
	Intensity	The intensity of the alert was (1=Too weak to 7=Too Strong)
	Timing	The timing of the alert was… (1=Too early to 7=Too late)
	Helpful	Rate how helpful the LDW was in identifying lane departures Not helpful (1) - Very Helpful (7)
	Affected Driving	The LDW affected my driving Negatively (1) - Very Likely (7)
	Interpretation	Ability to interpret the information presented by the alert was... Very Difficult (1) - Very Easy (7)
	Understand	Ability to understand why the alert was presented was... Very Difficult (1) - Very Easy (7)
	Trust	To what extent did you trust the LDW system? (0=Not at all, 1= Slightly, 2= Moderately, 3=Very Much, 4= Extremely)
	Rely	To what extent did you rely the LDW system? (0=Not at all, 1= Slightly, 2= Moderately, 3=Very Much, 4= Extremely)
	Comfort	How would you rate your level of comfort when the lane departure warning corrected your steering? (0=Not at all comfortable, 1= Slightly comfortable, 2= Moderately Comfortable, 3=Very Comfortable, 4= Extremely comfortable)
	Reliable	How reliable was LDW? (0=Not at all reliable, 1= Slightly reliable, 2= Moderately reliable, 3=Very reliable, 4= Extremely reliable)
	Confidence	What was your level of confidence in the LDW system? (0=Not at all confident, 1= Slightly confident, 2= Moderately confident, 3=Very confident, 4= Extremely confident)
	Want	Would you want a lane departure warning system on your next vehicle (0=No, 1=yes)
	Pay	How much would you be willing to pay for LDW

Hypotheses

It was hypothesized that novice and experienced drivers would have differing opinions about the lane departure warning system technology. Moreover, it was hypothesized that the novice driver's would have different responses to the automatic steering input, which in turn would result in degraded driving performance for young males in particular. The three hypotheses are shown in Table 5.

Table 5: Hypotheses

Hypothesis 1	When responding to the warning, the novice drivers will behave differently than the experienced drivers	$(\mu Novice \neq \mu\ Experienced)$
Hypothesis 2	The novice and experienced drivers will differ in their opinions about the lane departure warning system technology	$(\mu Novice \neq \mu\ Experienced)$
Hypothesis 3	The performance of the novice male drivers after the warning will be worse than the performance of female novice drivers and experienced male drivers	$(\mu MaleNovice < \mu\ FemaleNovice\ \&\ \mu\ MaleExperienced)$

Participants

Eighteen participants between the ages of 16 and 18 and eighteen participants between the ages of 35 and 55 completed participation in the study. Both age groups were balanced for gender. Participants between the ages of 16 and 18 were also stratified for age such that there were three males and three females of 16 years, 17 years, and 18 years.

Apparatus

The National Advanced Driving Simulator (NADS) is located at The University of Iowa's Research Park. It consists of a 24-foot dome that houses a 1996 Chevrolet Malibu Sedan. All participants drove the same vehicle. The motion system on which the dome is mounted provides 400 square meters of horizontal and longitudinal travel and ±330 degrees of rotation. The driver feels acceleration, braking, and steering cues as if he or she were driving a real vehicle. A total of eight projectors inside the dome display 360 degrees of scenery and environment. Each of the three front projectors has a resolution of 1600 x 1200; the five rear projectors have a resolution of 1024 x 768. The edge blending between projectors is five degrees horizontal. The NADS produces a complete record of vehicle state (e.g., lane position) and driver inputs (e.g., steering wheel position), sampled at 240 Hz.

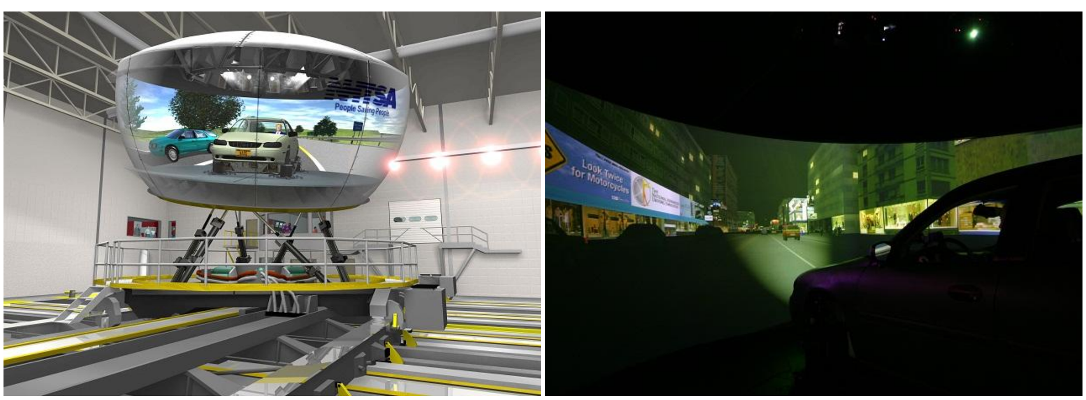


Figure 5: NADS-1 Driving Simulator (left) with a Driving Scene from Inside the Dome (right)

The cab was equipped with a Face Lab™ 4.0 (Seeing Machines, Canberra, Australia) eye-tracking system that was mounted on the dash in front of the driver's seat above the steering wheel. The worst-case head-pose accuracy is estimated to be about 5º. In the best case, where the head is motionless and both eyes are visible, a fixated gaze may be measured with a root mean square error of 2º.

Lane Departure Warning System

The simulation study utilizes a lane departure warning (LDW) system with a strong active intervention warning modality. Active warnings provide some extent of automatic partial control of a vehicle's behavior (e.g., direction, speed) through steering/braking. While there are currently no published active warning requirements, the torque input to the steering wheel was modeled and validated to the greatest extent possible using data available from the Vehicle Research and Test Center (VRTC). The strong steering torque was used as a warning to the driver that they would depart the lane boundary and consisted of a 6 N-m input in the direction necessary for appropriate lane return. The LDW simulation was accomplished by condensing the desired features and salient performance specifications into an algorithm that ran in real-time on the NADS-1. The use of an icon was implemented to indicate the status of the system (i.e. on or off) and was present for all participants.

LDW systems generally use a camera that employs image recognition algorithms to recognize various types of lane edge markings. The LDW simulation used in this study did not use a camera, and instead assumed perfect detection and interpretation of lane edge markings. Thus, there were no unintended false positive or false negative warning cues. The LDW algorithm triggered warnings based on lane position and was active for the entire drive with no need for the driver to press a button to activate the system. Consistent with current LDW systems, a minimum speed threshold of 35 mph was used to deactivate the system at lower speeds.

The NADS simulation environment supports the measurement of lane departures through the SCC_Lane_Deviation cell, described in Table 6. The lane offset was measured with respect to the center of the lane, using the center of gravity (CG) of the vehicle as the reference point. A corridor differed from a lane and was defined only in intersections. The vehicle heading in the lane, along with the wheelbase and track width of the car, were used to determine the exact moment of lane departure of any given wheel.

Table 6: SCC_Lane_Deviation Cell Specification

Element Type	**Element Description**	**Element Values & Units**
Float	Lane type	-1 = corridor 1 = lane 0 = error
Float	Lane deviation	Offset in feet: Negative = left Positive = right
Float	Lane width	Width in feet

Scenario

<u>Roadway Environment</u>

The simulator environment for this study provided a roadway network suited to assess distracted driver performance in the three road departure scenarios. To place the driver into these scenarios, a roadway design used for previous NHTSA Road departure research program was adapted (McGehee, Lee, Rakauskas, Ward & Wilson, 2007). The roadway is a two-lane bi-directional rural highway with standard 3-meter lanes and 1-meter shoulders. This roadway type is representative of the most common roadway departure crash scenarios described in (Najm et al., 2002).

The database was designed such that there were long two-lane highway straight-aways as well as a variety of left and right curves. The drive was approximately 30 minutes. The speed limit varied between 55 mph, 45 mph and 25 mph, depending on the radius of each of the 11 curves in the database. Among the 11 curves, three radii were used: 1000, 800 and 250 meters (see Figure 6).

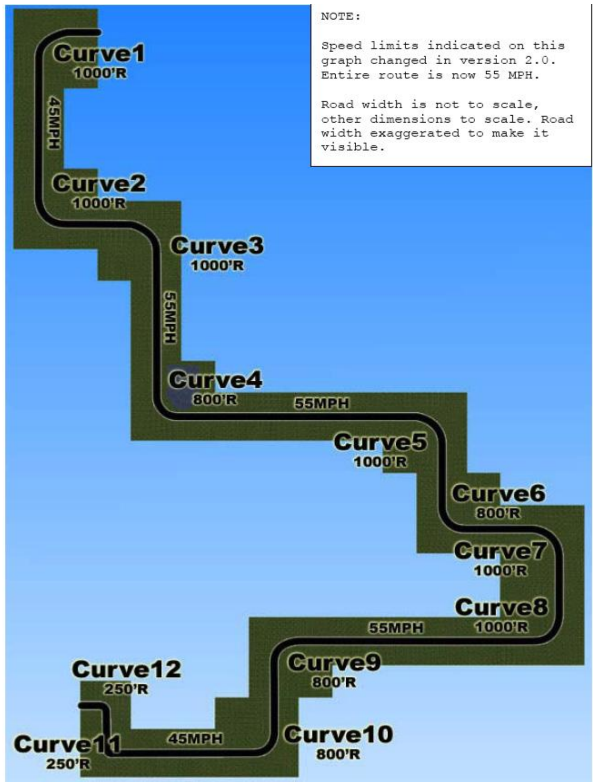


Figure 6: Conceptual Description of Roadway Database

The location of distraction events on straight roadway segments was selected to occur on portions of road such that the driver would be fully recovered from any previous curve negotiation. The location of distraction events in curve entries was selected such that the event occurred during the spiral entry prior to point of curvature (see Figure 7 & Appendix B).

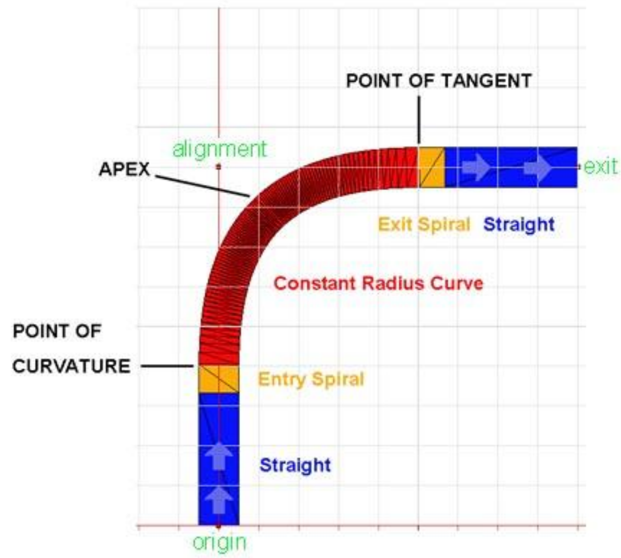


Figure 7: Curve Geometry Decomposition

For realism, and to provide urgency for the driver to return to their lane, oncoming traffic was present throughout the drive at an approximate rate of one vehicle per mile.

Events

The selection of scenario events was made by first looking at data from the Federal Analysis Reporting System (FARS). In 1998, FARS data estimated that 992,000 crashes involved vehicles departing the roadway (Szabo & Norcross, 2007). Such crash types generally occur at highway speeds and in rural areas and involve a single vehicle that departs the road. While lane departures do occur on multilane roadways and freeways, such departures usually result in non-injury property damage crashes (sideswipes, curb strikes and guard rail scrapes). Since LDW crash events vary by road type and traffic density (Najm et al., 2002), choosing events that can map onto real-world data is important (Ference, Szabo & Najm, 2007).

While there were a number of event options for this study, their differences are mainly associated with road type. When selecting road type, there are several to consider:

1. Multilane divided freeways
2. Two lane highways
3. Multilane arterials
4. Two lane arterials

Among these road types, vehicle miles traveled (exposure) and crash rates were examined. In the US, there are more rural roadway miles than urban freeways. It is well known that the speeds are generally higher on rural highways and the roadway environment is less forgiving. In urban areas, roadways have wider paved shoulders and guardrails, on rural highways, shoulders are often unpaved and less well maintained—and guard rails are less frequent. Consequently, the majority of rural road lane departure crashes (85.4 percent) occur on non-freeways. Of these non-freeway crashes, about 90.1 percent occur on undivided rural two-lane roads

(Ference et al., 2007; Najm et al., 2002). Multilane arterial road departures are bound by curbs and generally occur at slower speeds.

Given that a rural highway would be the road type, consideration for events that will have the best potential to map onto real world data is possible. From Najm et al. (2002), the most common events in these rural highway road departure crashes occur where the driver:

1. Drifts off road to the right
2. Drifts over the centerline, with on-coming traffic
3. Fails to keep lane in a left curve entry.

Because these are the most common crashes and ones that are generally the most injurious and fatal, these events were chosen for the study.

Distraction Tasks and Controlled Departure

To ensure a road departure at the specified events, it was necessary to force the driver out of their lane. To support this, it was essential to take the driver's eyes off the road just prior to the lane departure events. Thus the opportunity to gain an understanding of behaviors associated with the lane departure warning in conjunction with distracted driving is present. Although there are many distracters that can achieve this, it was important to choose a task that could reliably and repeatedly insure that the driver's eyes are off road for several seconds. Because drivers are able to use peripheral vision to monitor and maintain lane position, it was crucial that the driver's gaze be directed away from the forward view. Moreover, it was desired that the primary task be continuous to ensure that when the driver removed their attention from the road, it remained off the road until the lane departure had been triggered. To achieve this, a simulated insect task was used as the primary distracter, which was tied to the planned lane departures (see Appendix C).

Secondary distracter tasks were used to help to mask the importance of the primary distracter. While the secondary distracter tasks were not associated with planned lane departures, it was anticipated that some participants would have occasional unplanned lane departures during these tasks. These unplanned departures assisted in further masking the planned lane departure associated with the primary distracter task. The secondary tasks included inserting a CD and finding a given track and answering trivia questions on a touch screen.

Primary Distracter Task

Bug Catch Task

The bug catch task required participants to turn and reach into the back seat to catch a bug by tracing the path of an insect on a touch screen display. The task began with an auditory buzz noise that simulated the presence of the insect, which continued to buzz until the participant successfully "caught" it by touching the insect with their finger (see Figure 8). The design of the insect ensured that it would be impossible to catch until the lane departure occurred. The insect was also designed to provide variable lengths for the distracter task depending upon the needs of a particular situation or participant. An algorithm directed the insect away from the participant's finger in random directions at varying speeds until the lane departure was successful, at which time the bug maintained a random path that did not avoid the participant's finger and it became possible to quickly catch the insect (see Appendix C).

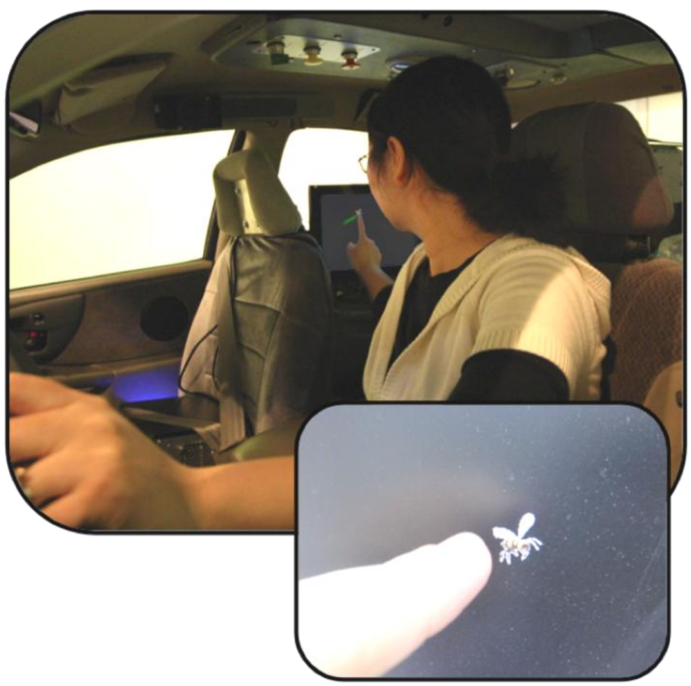


Figure 8: Bug Catch Task

Secondary Distracter Tasks

Trivia Game

The trivia game task utilized a handheld touch screen interface mounted on the dash of the car (see Figure 9) and instrumented to record screen touches into a raw data stream. The trivia task involved receiving a trivia question through the vehicle's audio system and selecting one of three answers on the touch screen by tapping it. The questions were variable in length and difficulty and are detailed in Table 7 below. Visual feedback was given for correct or incorrect responses and positive or negative point values were attributed accordingly. The feedback and point values were intended to encourage the participant to place value on answering correctly and thus take time and effort to think about the question and correct answer (see Appendix D).

Table 7: Trivia Game Event Order and Description

Event	**Description**
Trivia #1	"What famous document contains the sentence: We hold these truths to be self evident; that all men are created equal"
Trivia #2	"What color does acid turn when applied to litmus paper"
Trivia #3	"Who blinks more-men or women?"
Trivia #4	"What is the largest freshwater lake in the world?"

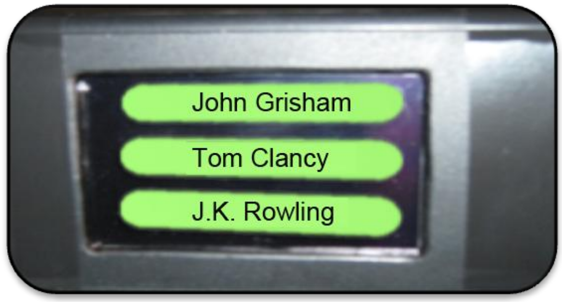


Figure 9: Trivia Game Touch Screen Interface

CD Task

The Compact Disk (CD) task involved removing a CD from the visor located above the driver, putting the CD into the CD player, finding the requested track, listening for the start of music, ejecting the CD, and putting it back in the visor. There were five CDs available to the driver four of which were used for the main drive data collection, and are detailed in Table 8 (see Appendix D).

Table 8: CD Task Event Order and Description

Event	**Description**
CD #1	"Advance to track 6 on the Aerosmith CD"
CD #2	"Advance to track 9 on the Toby Keith CD"
CD #3	"Advance to track 11 on the Frank Sinatra CD"
CD #4	"Advance to track 13 on the Michael Jackson CD"

Controlled Departure

In order to cause participants to leave their lane at the desired events, it was necessary to force the driver out of the lane when their attention was directed away from the forward road. Moreover, it was imperative that participants assumed their lack of attention to the road was the cause of the departure. In order to accomplish both of these, specific aim was taken to ensure that the algorithm used to push the vehicle from the lane had appropriate timing and was as realistic as possible. A pulse was created that lasted almost 2 seconds and represented a target heading angle in the lane. The difference between this target heading angle and the driver's actual heading angle was used as an error term into a proportional controller. The controller generated a steering signal that was added to the driver's actual steering input.

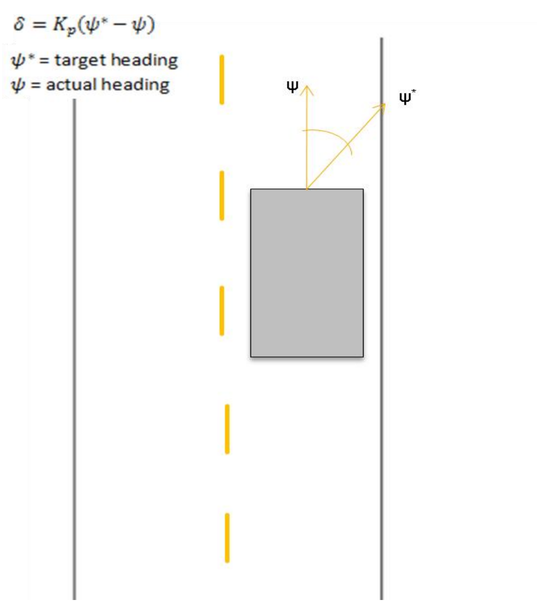


Figure 10: Proportional Controller Used to Create Steering Input

The push needed to be undetectable in that it would not cause the steering wheel to turn, yet still affect the dynamics of the simulator, and that the driver would not feel the effects of the lateral movement. To achieve this, the lateral acceleration of the car due to the steering disturbance was estimated from the dynamics properties and subtracted from the motion signal to ensure that the driver didn't 'feel' the disturbance (see Figure 11). If the driver received a warning, then the push immediately ended. If they fought against the disturbance or it lasted longer than 1.8 seconds, then the push was canceled. If either of these occurred, a drift abort was recorded.

$$a_y = \frac{V^2}{57.3\, Lg + KV^2}\left(\frac{\delta}{21}\right)$$

L = Wheel Base (ft)
V = Speed (ft/s)
g = Gravity (ft/s^2)
K = Understeer Gradient (deg/g)
δ = Handwheel Angle (deg)

Figure 11: Predicted Lateral Acceleration for Subtraction from Motion Cue

Additional Technologies

In order to mask focus on the LDW, additional systems were implemented in the simulator and participants were told that they were recruited to evaluate several new in vehicle technologies.

Speed Violation Warning

This technology was described to participants as being designed to alert drivers that they were violating the speed limit. If the speed of the vehicle exceeded eight miles per hour over the posted speed limit an auditory warning was activated. The warning was implemented through the vehicles sound system and told the driver that they were performing a "speeding violation." The voice for this system was computer generated to indicate that it was a technology.

Trivia Game Alert System

The trivia game played two roles in the study. Previously, it was described as a secondary distraction task that helped mask the importance of the primary distraction task. However, participants were told it was one of the new technology systems they recruited to evaluate. This technology was described to participants as being designed to aid drivers in staying alert by periodically engaging them in a trivia game. The voice for this system was computer generated to indicate that it was a technology.

Procedures

Screening Procedure

Recruitment was performed using the NADS database that currently contains over 5,600 names of potential participants that have indicated an interested in participating in driving studies. An email was sent to all potential participants about the study (see Appendix E). Phone screenings (see Appendix F) were conducted to determine eligibility based on the following inclusion/exclusion criteria. For the adults, potential participants had to be between the ages of 35 and 55 years of age and in good general health. Adult participants must have had a current valid driver's license, have been a licensed driver for at least two years, and drive a minimum of 10,000 miles per year. For the novice group, potential participants had to be between the ages of 16 and 18 years of age and in good general health. Novice participants must have had a current valid driver's license or permit and have been a licensed driver for at least six months, however did not have a minimum required miles driven per year. Restrictions on any participant's driver's license were limited to vision and participants could not require the use of any special equipment to drive such as pedal extensions, hand brake or throttle, spinner wheel knobs, or other non-standard equipment that would limit interpretation of accelerator pedal, brake pedal, or steering inputs. Furthermore, participants could not have had prior experience with NADS studies involving new technology research. By self-report of the make and model of their current vehicle, participants could not have currently owned a vehicle equipped with a LDW system. Participants who never engage in distracting tasks while driving were excluded in the pre-study screening by answering "no" when asked "do you ever engage in behavior that may be distracting while driving such as: talking on your cell phone, sending or receiving text messages, eating, sending or receiving emails, or reading?"

For the safety of the participants, participants were excluded for serious illnesses, diabetes, seizures, epilepsy, migraines, inner ear problems, psychiatric illnesses, and severe motion sickness. Pregnant women were excluded. To maintain the integrity of the data collected, participants with sleeping disorders and those who were on medications that induce sedation or drowsiness were also excluded.

If, following the phone screen eligibility questions, participants were still eligible, they were scheduled for a date and time to come to the National Advanced Driving Simulator at The University of Iowa Research Park for their main study visit.

Briefing

Upon arrival at the facility, participants were taken to a briefing room. To prevent participants from becoming fixated on the LDW, they were told during screening and briefing that they were going experience a vehicle with a number of innovative design features. During briefing, participants completed an informed consent document (see Appendix G), a video release statement, a payment voucher, and the NADS Driving History Questionnaire (see Appendix H) that asked questions about demographics, driving history, current driving practices, and medical issues. To assure familiarity with the LDW without focusing the participant's attention specifically on the LDW, participants watched a PowerPoint Presentation (See Appendix I) that did the following: identified the purpose of the study as the evaluation of several new in vehicle technologies, introduced participants to the simulator cab, trained participants on the LDW as well as the other new technologies (i.e. Speed Violation Warning and Trivia Game), provided participants information about the drives, and trained them on the distracter tasks.

The training portion of the PowerPoint included slides about the appearance, location, and functionality of the LDW, other technologies and distraction tasks. The explanation of the LDW was consistent with the type of information provided in a vehicles' owner's manual. It provided the information necessary to allow the participants to understand what the warning looked like and felt like. Pictures, videos, and audio sounds were incorporated.

Drive

Following the briefing, participants were taken into the simulator for their drive. While inside the vehicle, participants were shown each of the new technologies and distraction tasks and reinstructed on how to do each of the tasks (see Appendix J).

To assist in adaptation of the test vehicle prior to the actual data trial, participants experienced about five minutes of a practice segment. In order to avoid uncontrolled (participant-initiated) lane departures, the practice segment of the drive primarily involved low speeds and local unmarked roads. To develop participants' experience with the feel of the LDW system, participants were asked to make intentional lane departures to the left and to the right. Participants were also asked to speed up to ten miles per hour over the speed limit to experience the speed warning and mask the importance of the LDW warning. Once the participant was comfortable with the vehicle, the distracter tasks were briefly practiced while driving.

During the main portion of the drive participants were instructed to drive as they normally would and engage in the distraction tasks when they occurred. Specifically, the PowerPoint training presentation (Appendix I) instructed drivers to "drive in the simulator vehicle in your normal manner on rural roads". Distracter tasks and forced lane deviations occurred. The lane deviations were implemented during the "primary" distracter task, but did not occur during every "primary" distracter task.

Debriefing

After the drive, participants were escorted to a debrief room. During the debriefing process, participants completed a Wellness survey to assess how they physically felt after driving in the simulator, a realism questionnaire to assess their view of the realism of simulator and simulated environment, a Situational Awareness Rating Technique (SART) questionnaire (Taylor, 1989) to assess situational awareness, and an acceptance survey to assess the participant's level of acceptance of the LDW system. After the completion of the acceptance survey, a debriefing statement (see Appendix K) was provided that stated the real purpose of the study. The debriefing statement requested that the participant refrain from discussing specific details about the study, including the experimental drives, until data collection was completed. After reading the debriefing script, participants were asked if they had any additional questions, paid for their time, and were allowed to go home.

Data Analysis

Data was analyzed using SAS statistical analysis software (version 9.2). A total of 108 data points were used for the analysis (18 participants X 2 Conditions X 3 Events).

<u>Removing Events in Which Warning is not Leading Indication of Departure</u>

In order to identify participants that looked away from the distraction task toward the forward road before the warning initiated, all events that contained a drift abort value were removed from analysis. A drift abort was recorded when the forced departure gives up due to prolonged exposure without departure or a significant counter steer is detected. These are evidence that the driver has noticed the forced departure and is counteracting it, causing it to expire without its intended departure. If the driver has noticed the forced departure, then their reaction is no longer an effect of the warning and thus not of value to the study.

Furthermore, to ensure that all instances in which the driver's reaction occurred before the warning were removed from analysis, events in which participants had a negative local lateral speed at the departure were also eliminated. This value describes the lateral speed of the vehicle at the departure in terms of the vehicle's reference frame (see Appendix L for sample plot). A negative value indicates that the lateral speed at the time of departure is opposite the direction of departure and is evidence that driver has began correcting for the departure before the warning occurs. If the driver is correcting for the departure before they have crossed the departure threshold that the warning uses to trigger an alert, then their reactions are no longer effects of the warning and are thus not of value to the study.

Finally, a video review of the data was conducted for each participant's 3 events. If the participant reacted to the lane departure before the warning initiated, the event was removed from analysis. If it is subjectively obvious that the driver is reacting before the warning triggers, then their reactions cannot be tied to the warning and thus the event is not of value to the study.

Dealing with Events in Which Driver Departs Opposite the Intended Direction

The three events that each driver experienced were intended to gather information about their reaction to the warning in the three most common events in rural road departure crashes. If the driver initially departed the lane opposite the direction intended, the data no longer fulfills its intention.

Thus, if the driver initially departed left during the right departure event then that data point was removed from analysis. The same is true for those that initially departed right during the left departure event.

The event that simulates driver's failures to keep their lane in a left curve entry posed to be more difficult. 17 of the 36 participants departed the curve in the intended direction (to the left) while 19 departed to the right. With this nearly 50/50 split, it was decided that the event would be split by departure direction and analyzed separately. This resulted in four events for analysis: left departure, right departure, curve left departure, and curve right departure.

A total of 28 data points were excluded from analysis due to the warning not being the initial indicator of departure or departure in the incorrect direction on a left or right event (14 curve event points, 6 right event points, and 8 left event points).

Removing Extreme Outliers

A univariate analysis by condition was conducted on the remaining data to determine the normality and homogeneity of the data. The outliers greater than or equal to three standard deviations from the mean of each condition were removed from analysis to reduce skewness and kurtosis and improve normality of the data.

Behavioral Effects of Primary Distraction Task

The primary distraction task, the bug catching task, was designed to end upon departure in order to avoid behavioral effects associated with the distraction task rather than the lane departure warning. However, to ensure that there were no effects related to the distraction task, analysis of participant's performance associated with the distraction task was conducted. As expected, no significant differences were seen between experience or gender levels. On average, male participants took 5.4 seconds to catch the bug while female participants took 6.6 seconds. Moreover, novice drivers spent an average of 5.6 seconds on the task and experienced drivers spent 6.4 seconds. Again, none of the differences, or their associated interactions, were statistically significant.

Statistical Tests

A factorial General Linear Model was then used to compare the dependent measures by condition (novice, experienced), gender (male, female), event (left, right, curve left departure, curve right departure), and scenario (order 1, order 2, order 3). The primary interest was differences by condition, however all main effects and interactions were included in the model.

After initial analysis, and as expected, event was significantly different for some measures. However, there was no difference in event for any measure shown to be statistically different by condition. In an effort to equalize cell size and variances, the data was aggregated across event. Each participant's three events were averaged resulting in equal cell sizes of 9 data points per condition and gender combination (36 total data points). The result was an overall measure based on the entire drive which encompassed the three most common rural road lane departure crash events. A post hoc t-test was used to determine the least significant difference for the main effects.

CHAPTER 3: RESULTS

Table 9: Summary Table of Vehicle Based Results

Dependent Measure Source	**Degrees of Freedom**	**Degrees of Freedom Error**	**MS**	**F**	**P**
Time to Accelerator Release					
Condition	1	18	12.3	0.35	0.561
Gender	1	18	81.5	2.33	0.144
Condition*Gender	1	18	14.9	0.43	0.522
Time to Initial Steering Response					
Condition	1	24	0.09	0.38	0.542
Gender	1	24	0.14	0.57	0.458
Condition*Gender	1	24	0.81	3.39	0.078
Magnitude of Initial Steering Response					
Condition	1	24	772	13.91	0.001
Gender	1	24	51.1	0.92	0.347
Condition*Gender	1	24	164	2.96	0.098
Number of Steering Reversals					
Condition	1	24	46.7	10.04	0.004
Gender	1	24	0.11	0.02	0.878
Condition*Gender	1	24	0.52	0.11	0.741
Peak Steering Rate					
Condition	1	24	4,400	1.44	0.241
Gender	1	24	6,900	2.28	0.144
Condition*Gender	1	24	2,600	0.88	0.359
Peak Steering Jerk					
Condition	1	24	210,000,000	4.34	0.048
Gender	1	24	95,000,000	1.97	0.173
Condition*Gender	1	24	96,000,000	1.99	0.171
Standard Deviation of Lane Position					
Condition	1	24	1,000	0.70	0.411
Gender	1	24	2,900	1.99	0.171
Condition*Gender	1	24	7,800	5.43	0.029
Maximum Extent of Lane Exceedance					
Condition	1	24	1.51	1.01	0.324
Gender	1	24	0.82	0.55	0.465
Condition*Gender	1	24	7.66	5.12	0.033
Duration of Lane Exceedance					
Condition	1	24	2.58	0.42	0.523
Gender	1	24	0.77	0.13	0.726
Condition*Gender	1	24	0.44	0.07	0.792
Lane Exceedance Exposure (Area)					
Condition	1	24	24,000	1.87	0.184
Gender	1	24	1,200	0.10	0.760
Condition*Gender	1	24	15,000	1.18	0.288
Change in Velocity					
Condition	1	24	0.90	0.31	0.581
Gender	1	24	5.61	1.95	0.176
Condition*Gender	1	24	0.01	0.00	0.951

	df	**N**	**χ^2**	**P**
Run-off road				
Condition	1	36	0.36	0.55

Separated by Error Term

Interaction Results

All measures were analyzed using the general linear model based on the aggregated data. Of the measures analyzed, there were two statistically significant interactions. Both were seen between condition and gender. The standard deviation of lane position, $F(1,24)=5.43$, $p=0.029$, and the maximum lateral distance $F(1,24)=5.12$, $p=0.03$ that the leading edge of the vehicle extends out of the lane from the initial steering response to the warning to stabilization in the lane. The plots for these interaction results are shown below in Figure 12 and Figure 13 below.

Experienced males had an average standard deviation of lane position that was approximately 75 centimeters and experienced female's average standard deviation of lane position was approximately 87 centimeters. The average standard deviation of lane position for novice males was approximately 115 centimeters and novice females had an average standard deviation of lane position of approximately 68 centimeters. The Least Significant Difference test with an alpha of 0.05 showed novice male drivers to have statistically greater variability in lane keeping than both experienced male drivers and novice female drivers.

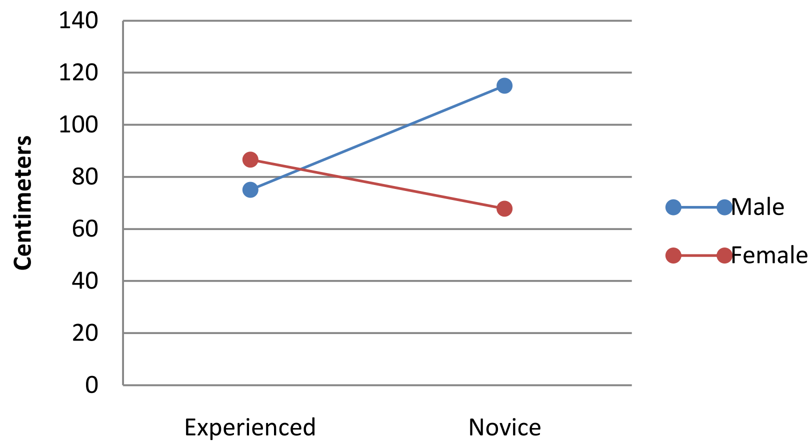


Figure 12: Standard Deviation of Lane Position Interaction

The average maximum lateral lane exceedance for experienced males was approximately 0.9 meters and was approximately 1.5 meters for experienced females. The average maximum exceedance for novice males was approximately 2.2 meters and novice females had an average maximum lane exceedance of approximately 1.0 meters. The Least Significant Difference test with an alpha of 0.05 showed novice male drivers to have statistically greater maximum departure distances than both experienced male drivers and novice female drivers.

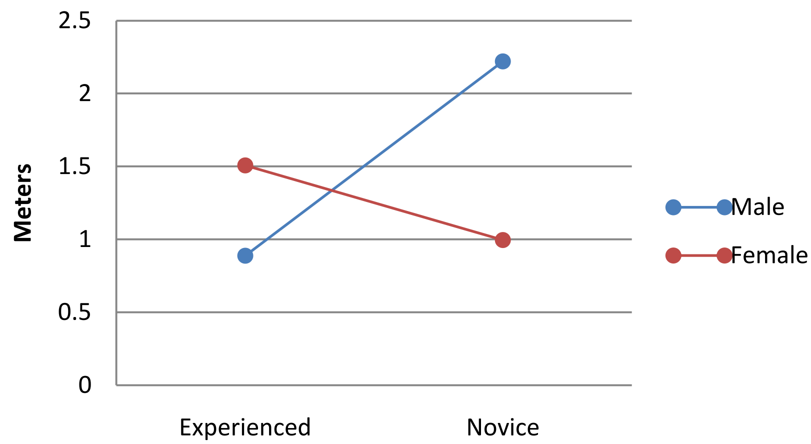


Figure 13: Maximum Lane Exceedance Interaction

Results of Vehicle Based Measures by Condition

The vehicle based measures were also analyzed using the general linear model based on the aggregated data. Of the measures analyzed, four measures proved to be significantly different between the novice and adult drivers.

<u>Initial Steering Response</u>

Teen drivers had an initial steering response of significantly lower degree than the adults F(1,24)=13.91, p=0.001. The initial steering input of adults was a just over 30 degrees while the novice drivers had an input that was more than eight degrees less, at about 21 degrees (see Figure 14). Error bars are shown using standard error by condition (Experienced=1.70, Novice=1.72).

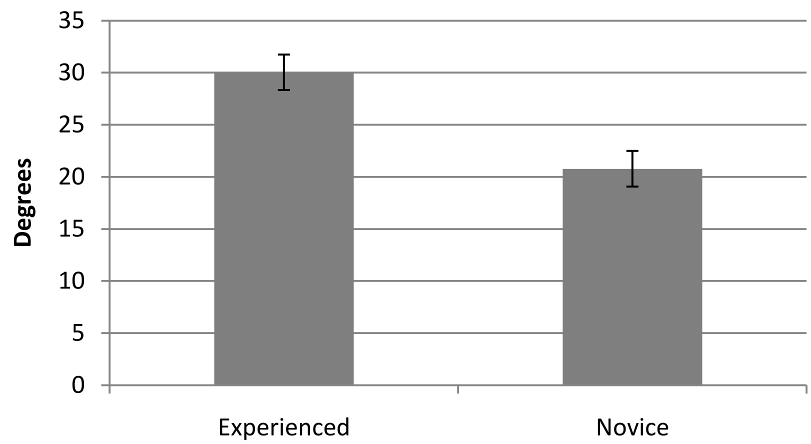


Figure 14: Initial Steering Response after the Warning by Condition

Peak Steer Jerk

Teen drivers had significantly lower peak steering jerk than the adults $F(1,24)=4.34$, $p=0.048$. Figure 15 shows that the adult drivers had a peak jerk of 19,600 degrees per second cubed while the novice driver's change in acceleration was only 14,700 degrees per second cubed. Error bars are shown using standard error by condition (Experienced=1,952, Novice=1,592).

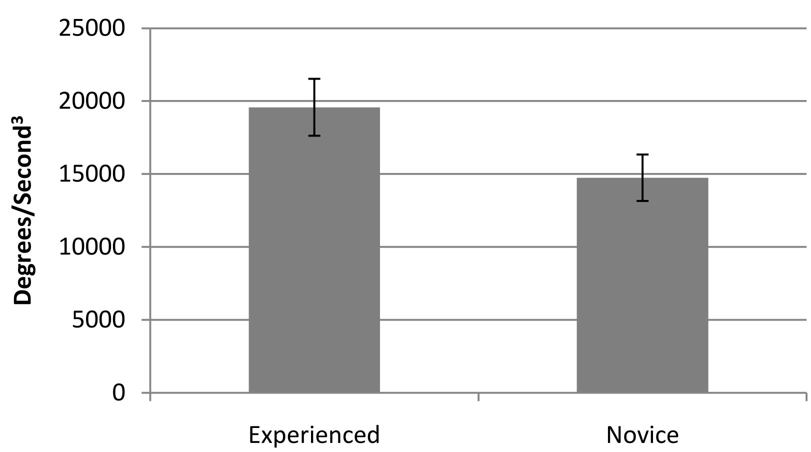


Figure 15: Peak Steering Jerk of Event by Condition

<u>Steering Reversals</u>

Novice drivers also had significantly fewer steering reversals than the more experienced adults $F(1,24)=10.0$, $p=0.0041$. Adults had an average of 8.62 reversals during an event while novice drivers had an average of only 6.34 reversals (see Figure 16). Error bars are shown using standard error by condition (Experienced=0.52, Novice=0.46).

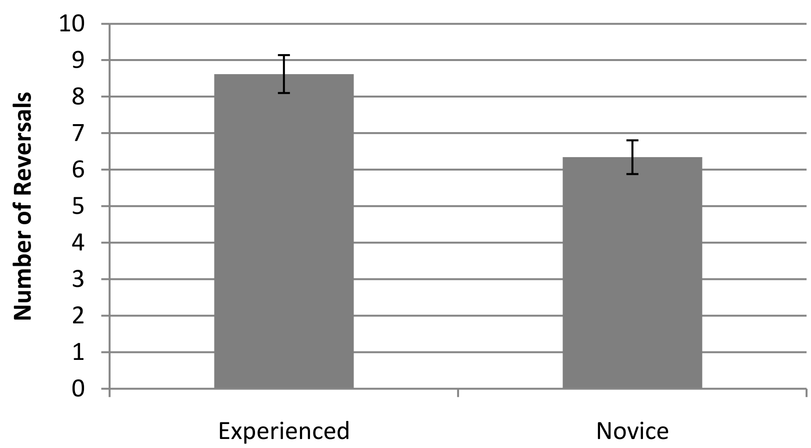


Figure 16: Number of Steering Reversals by Condition

Results of Subjective Measures

Table 10 below shows the summary table for the subjective measures that were analyzed. Of the 15 measures analyzed, there was one statistically significant main effect of the subjective measures and there were no significant interactions.

Table 10: Summary Table of Subjective Results

Dependent Measure Source	Degrees of Freedom	Degrees of Freedom Error	MS	F	P
Helpful					
Condition	1	33	2.76	0.64	0.429
Affected Driving					
Condition	1	33	0.034	0.01	0.919
Interpretation					
Condition	1	33	1.045	0.34	0.562
Understand					
Condition	1	33	0.470	0.26	0.613
Catch Attention					
Condition	1	33	3.70	1.08	0.305
Distracting					
Condition	1	34	1.00	0.30	0.587
Feeling					
Condition	1	34	5.44	1.51	0.228
Intensity					
Condition	1	34	1.78	0.98	0.330
Timing					
Condition	1	34	7.11	11.83	0.002
Comfort					
Condition	1	34	0.028	0.02	0.884
Reliable					
Condition	1	34	0.028	0.02	0.877
Confidence					
Condition	1	34	0.028	0.02	0.885
Rely					
Condition	1	34	1.78	1.77	0.192
Pay					
Condition	1	10	25,6287	1.27	0.286

	df	**N**	**χ^2**	**P**
Want				
Condition	1	35	0.686	0.407

Separated by Error Term

As shown if Figure 17, the novice drivers rated the timing of the warning on the late side of the scale while the adults rated the timing of the alert on the early side of the scale, $F(1,34)=11.83$, $p=0.0016$. With a response of 1 being too early and 7 being too late, the adults gave the LDW a score of 3.67 while the novice drivers rated it with a 4.56. Error bars are shown using standard error by condition (Experienced=0.86, Novice=1.07).

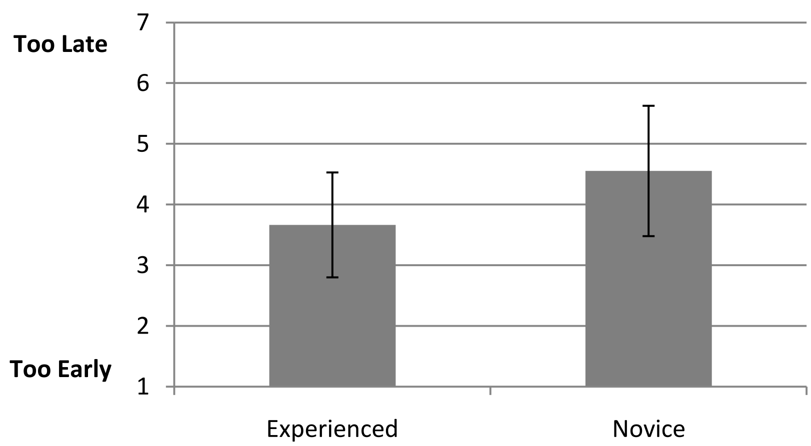


Figure 17: Driver Perception of the Timing of the Warning

CHAPTER 4: DISCUSSION

The results of the experiment with respect to differences by condition were robust. Initial analysis of the data using a full statistical model that included gender, event, scenario, & condition and utilized the individual data points, showed a statistical difference in three vehicle based measures for condition. Additionally, regardless of whether the extreme outliers were removed from the data, the same three measures proved to be different for condition. Finally, when the data was aggregated over the entire drive, the same three measures were statistically different by condition. As a result, the differences seen in these three measures (Initial Steering Response, Peak Steering Jerk, & Number of Steering Reversals) appear to be valid indicators of the reactions of the drivers.

Hypothesis 1

When responding to the warning, the novice drivers will behave differently than the experienced drivers ($\mu Novice \neq \mu Experienced$)

This hypothesis was confirmed by the data. Of the behavioral response measures analyzed, half of them showed significant differences between novice and experienced drivers. When a lane departure occurred due to distraction, novice drivers reacted with less input to the lateral control warning than their experienced counterparts. Novice drivers had a substantially smaller initial steering response than the experienced drivers as seen by a steering input that was nearly 10 degrees less. Not only did the input of the novice drivers lack in its amount of rotation, but it also lacked in the force and speed of the steering input. There was approximately a 5,000 degrees/second^3 difference in steering jerk between novice and experienced drivers. Overall, the behavioral responses of the novice drivers were weaker than those of the experienced drivers (μNovice < μExperienced). This is may be due to the young novice driver's inability to recognize the risks involved in driving and their associated higher levels of risk acceptance and skewed perceptions of risk. Stein and Allen's (1987) understanding of how the level of risk perceived effects a driver's acceptance threshold, and thus their behaviors, remain both relevant and applicable to these findings. Perhaps, young novices perception of themselves as more skillful and their estimations of personal risk as less than others as described by Engstrom et al. (2003) produced a false sense of control and a lack of urgency.

Hypothesis 2

The novice and experienced drivers would differ in their opinions about the lane departure warning system technology (μNovice $\neq$ μ Experienced)

Of the sixteen subjective measures collected, only one of the measures showed that novice drivers have statistically different opinions about a control intervention lane departure warning system as a new in-vehicle technology. Thus, the data clearly refute this hypothesis and points to a null (MNovice = MExperienced). The only subjective assessment about the lane departure warning system that proved to be statistically different between novice and experienced drivers was their opinion about the timing of the alert. Novice drivers thought the timing of the warning was significantly later than the experienced drivers.

These findings are particularly interesting given the statistical difference in reaction behaviors above. Novice drivers opined that the warning was presented too late, however they reacted with less input than the experienced drivers who rated the warning on the early side of the scale. It would be expected that if the novice drivers felt the warning was too late, they would react with more input to account for the delay. Instead, their response behavior shows less urgency. This can be seen as evidence of a disconnect between young novice driver's perceptions and behaviors (Deery, 1999).

Hypothesis 3

The performance of the novice male drivers after the warning will be worse than the performance of female novice drivers and experienced male drivers. (MMaleNovice < M FemaleNovice & M MaleExperienced)

The data confirms this hypothesis. Male novice drivers showed degraded performance compared to both the female novice and male experienced drivers. Female drivers did not seem to have an increase in performance related to increased experience with respect to the maximum lane exceedance and standard deviation of lane position. However, the performance of male drivers significantly improved with experience. The male novice drivers exceeded their lane approximately 1.3 meters further and had a standard deviation over 40 centimeters more than the experienced male drivers.

This finding is consistent with the literature in that there are larger differences in gender for young teenage drivers than for mid-aged, more experienced drivers (McKenna et al., 1998; Massie, Campbell & Williams, 1995). The differences found between experienced male and female drivers was minimal (11.6cm for standard deviation of lane position, 0.6m for maximum lane exceedance) and much more pronounced for the novice group (47cm for standard deviation of lane position, 1.2m for maximum lane exceedance).

Limitations & Future Work

A limitation of the study was the lack of a baseline drive. Without a baseline drive for the novice and experienced driver groups, it became difficult to evaluate the reactions to the warning separately from the reactions to the lane departure. Having a separate group of both novice and experienced groups drive the experiment exactly as is, with the exception of the warning would have allowed for a comparison between novice and experienced drivers with respect to their relevant norms. This limitation was mitigated by removing data for participants who responded prior to the warning, thus insuring for all data analyzed the warning was provided to the driver prior to the driver's response. In this way, we were able to minimize the impact of this limitation.

Another limitation was loss of data points. The findings are limited by a lack of valid event data for every event for every subject. This elimination of data points was due, primarily, to two contributing factors. The first was the location of the distraction task touch screen (the bug catching screen) within the vehicle. The protocol of the experiment required full diversion of the driver's attention from the forward roadway long enough to successfully depart their vehicle from the lane. However, the location of the distraction task touch screen resulted in a range of strategies of scanning behavior between the primary task of driving and the distraction task. Occasionally, the strategy employed by the driver resulted in a lack of full vision from the roadway when the departure occurred. The second factor that contributed to the loss of data points was the distance of the vehicle to the required departure lane line. The forced departure algorithm utilized a push that did not account for the driver's current lane position. When a driver maintained normal lane keeping on the opposite side of the lane as the intended departure, it was more difficult to successfully get them to depart in the intended direction. This resulted in some participants either correcting for the lane drift or incidents in which the push algorithm "gave up" due to prolonged exposure. Ultimately, it was a combination of these two factors that resulted in the loss of event data points for some participants.

As reasons for the differences in behavior to the warning are explored, additional information regarding participant's trust in automation and use of video games may have been useful. Perhaps experience with higher gain associated with video game based simulation transfers to high fidelity simulators and real world driving in a way that reduces the necessary inputs. Information regarding participant's trust in automation and use of video games may add some illumination to the differences in steering inputs and effects of simulation. It might have been interesting to determine if the weaker inputs seen by novice drivers could be attributed to their unique understanding of the ratio between inputs and outputs in video game based simulation that are not representative of driving an actual car or an advanced research simulator. Moreover, it would be interesting to investigate if the lack of input by novice drivers could be attributed to an increased trust in the automation of the lane departure warning system to accurately guide them toward their lane.

Conclusions

Evaluation of young novice driver's behavior, performance, and opinions with respect to a lateral control intervention as a lane departure warning was conducted in order to gain insight into how ADAS will affect young novice drivers compared to their older experienced counterparts. Eighteen young novice drivers and eighteen experienced drivers drove in a high fidelity motion based simulator, and while their forward vision was distracted, a controlled departure was implemented in order to evaluate their reactions to the LDW system.

Overall, young novice drivers reacted with less urgency than experienced drivers to a lateral control intervention lane departure warning. However, there was no evidence to support differences in the opinions of young novice and experienced drivers about the lateral control intervention lane departure warning. Nor was the lateral control intervention shown to alleviate the significantly worse performance of novice males as compared to novice females and experienced males.

There was strong evidence to indicate that young novice drivers behave differently than experienced drivers in reaction to a lateral control intervention lane departure warning. While more research is needed to further understand the differences, there is no evidence that current experiments regarding ADAS can be used to make assumptions about their effects on the young novice driver population.

APPENDIX A: POST DRIVE QUESTIONNAIRE

Study: CWIM2
Participant: ___________
Date: ___________

Lane Departure Warning Post Drive Acceptance Questionnaire

The following questions address ONLY the ALERT issued by the **Lane Departure Warning System**. This is the only system you will be asked to evaluate. The alert activated when your vehicle departed from the inside of the lane markings. Please read each question carefully and circle 1 - 7 for each question. If something is unclear ask the research assistant for help. Your participation is voluntary, and you have the right to omit questions you choose not to answer.

1	The alert...	Did not catch my attention 1	2	3	4	5	6	Caught my attention 7
2	The alert was...	Not Distracting 1	2	3	4	5	6	Very Distracting 7
3	My ability to hear/feel the alert was ...	Very Difficult 1	2	3	4	5	6	Very Easy 7
4	The intensity of the alert was...	Too Weak 1	2	3	4	5	6	Too Strong 7
5	The timing of the alert was...	Too Early 1	2	3	4	5	6	Too Late 7
6	Rate how helpful the lane departure warning was in identifying lane departures.	Not Helpful 1	2	3	4	5	6	Very Helpful 7
7	The lane departure warning affected my driving...	Negatively 1	2	3	4	5	6	Positively 7
8	My ability to interpret the information presented by the alert was...	Very Difficult 1	2	3	4	5	6	Very Easy 7
9	My ability to understand why the alert was presented was...	Very Difficult 1	2	3	4	5	6	Very Easy 7

The following questions address ONLY the ALERT issued by the **Lane Departure Warning System**. Please check the appropriate answer and describe your reasoning.

10. To what extent did you trust the lane departure warning system?
    - ❒ Not at all
    - ❒ Slightly
    - ❒ Moderately
    - ❒ Very Much
    - ❒ Extremely

What factors led to this degree of trust?

____

____

____

11. To what extent did you rely on the lane departure warning system?
    - ❒ Not at all

Figure A1: Post Drive Subjective Questionnaire

Study: CWIM2
Participant: __________
Date: __________

❒ Slightly
❒ Moderately
❒ Very Much
❒ Extremely

What factors led to this degree of reliance?

____

____

____

12. How would you rate your level of comfort when the lane departure warning sounded/caused vibrations in the steering wheel/caused the steering wheel to move? (*note: only one of these will be shown to the participant depending on their condition)
❒ Not at all comfortable
❒ Slightly comfortable
❒ Moderately comfortable
❒ Very comfortable
❒ Extremely comfortable

What affected your level of comfort?

____

____

____

13. How reliable was the lane departure warning system?
❒ Not at all reliable
❒ Slightly reliable
❒ Moderately reliable
❒ Very reliable
❒ Extremely reliable

What about the lane departure warning system's operation influenced how you rated its reliability?

____

____

____

14. What was your level of confidence in the lane departure warning system?
❒ Not at all confident

Figure A1 Continued

Study: CWIM2
Participant: __________
Date: __________

❒ Slightly confident
❒ Moderately confident
❒ Very confident
❒ Extremely confident

What about the lane departure warning system influenced how you rated your confidence in its operation?

____

____

____

15. Would you want a lane departure warning system in your next vehicle?
    ❒ Yes
    ❒ No

Why would/wouldn't you want a lane departure warning in your next vehicle?

____

____

____

16. How much would you be willing to pay for a lane departure warning system?

    $________________________

17. What was your degree of ***self confidence*** to handle lane departures?
    ❒ Not at all confident
    ❒ Slightly confident
    ❒ Moderately confident
    ❒ Very confident
    ❒ Extremely confident

Suggestions for improving the alert of the lane departure warning system:

____

____

____

____

Figure A1 Continued

APPENDIX B: SCENARIO MAP

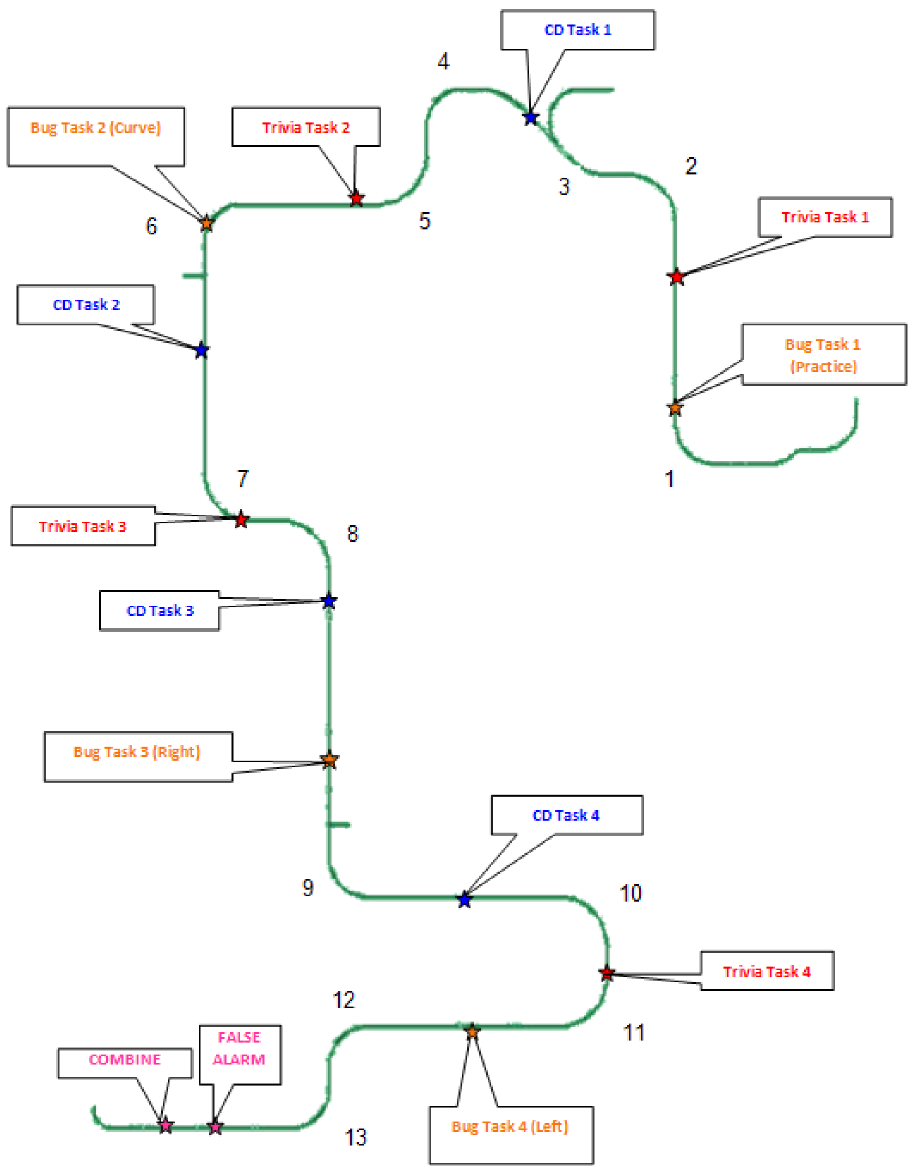


Figure B1: Scenario 1 Map of Events

APPENDIX C: BUG TASK SPECIFICATIONS

Table C1: Bug Task Specifications

BUG TASK 2-LEFT EVENT ID 2332	
RATIONALE	This is a primary distracter tasks that is associated with a planned road departure to the left while driving straight with an oncoming vehicle present. The oncoming semi is set to match the velocity of the driver so that they interact with it at approx the same location in relation to the event.
ROAD NETWORK REQUIREMENTS	Speed limit (in mph): 55 Overall length/distance needed to support event (in feet): 2,400 feet (1,200 to hear message, 1,200 to respond) Road type (lanes, surface): 2 driving lanes, paved surface, normal shoulders, ditch just beyond shoulder Intersection type: none Time of Day/Date: day
PREPARATION	The participant drives along a 2 lane rural road with narrow shoulders. An oncoming semi (Car13-LDW) is created when participant is 3000 feet away. The oncoming semi truck approximately 885 feet away from the start of the event and has an initial velocity of 50 mph and then matches velocity of own vehicle by sending ovvel to Set Dial. The speed limit is 55 mph The “Speeding Violation” message is suppressed during the time that the participant receives the message, so that he does not hear two messages at the same time.
START CONDITIONS	Driving along road and cross a road pad to trigger bug event.
ACTUAL EVENT	Event is located 3745 feet before curve 11 in Scenario 1, 3500 feet after second intersection in Scenario 2, and 4750 feet after curve 8 in Scenario 3 The event ID, 2332, is written to LogStream 4. The appropriate event order (12, 5, 8) is written to LogStream 3. 3 additional bug task 1 Triggers are created: • Scenario 1: B4S1 Initial audio, B4S1 Delete initial audio, B4S1 Final Audio • Scenario 2: B2S2 Initial audio, B2S2 Delete initial audio, B2S2 Final Audio • Scenario 3: B3S3 Initial audio, B3S3 Delete initial audio, B3S3 Final Audio The event initiates when the appropriate value (1) is sent to the AUX_Display2_SendTo Cell. This cell transmits (via several steps) to the AUX computer in the cab and drives the messages to be displayed. The bug task begins when SCC_Audio_Trigger changes to 2331 and plays while AUX_Display2_RecieveFrom=1. When participant touches bug screen, begin steering disturbance to left by sending 2 to SCC_Steer_Input initiating push to left. Stop sending to SCC_Steer_Input after 10 sec.
END CONDITIONS	When the driver resumes stability and continues driving along the road and AUX_Display2_RecieveFrom=0.
CLEANUP	The speeding violation message is reengaged. 0 is sent to Reset AUX_Display_SendTo.

Table C1 Continued

BUG TASK 3-RIGHT EVENT ID 2333	
RATIONALE	This is a primary distracter tasks that is associated with a planned road departure to the right while driving straight.
ROAD NETWORK REQUIREMENTS	Speed limit (in mph): 55 Overall length/distance needed to support event (in feet): 2,400 feet (1,200 to hear message, 1,200 to respond) Road type (lanes, surface): 2 driving lanes, paved surface, normal shoulders, ditch just beyond shoulder Intersection type: none Time of Day/Date: day
PREPARATION	The participant drives along a 2 lane rural road with narrow shoulders. There is assorted oncoming traffic at the rate of about 1 vehicle every 60 seconds The speed limit is 55 mph The "Speeding Violation" message is suppressed during the time that the participant receives the message, so that he does not hear two messages at the same time.
START CONDITIONS	Driving along road and cross a road pad to trigger bug event.
ACTUAL EVENT	Event is located at 4000 feet before third intersection in Scenario 1, 4041 feet before curve 12 in Scenario 2, and 1902 feet after second intersection in Scenario 3. The event ID, 2333, is written to LogStream 4. The appropriate event order (5, 12, 9) is written to LogStream 3. Create 3 additional bug task 1 Triggers: • Scenario 1: B3S1 Initial audio, B3S1 Delete initial audio, B3S1 Final Audio • Scenario 2: B4S2 Initial audio, B4S2 Delete initial audio, B4S2 Final Audio • Scenario 3: B2S3 Initial audio, B2S3 Delete initial audio, B2S3 Final Audio The event initiates when the appropriate value (1) is sent to the AUX_Display2_SendTo Cell. This cell transmits (via several steps) to the AUX computer in the cab and drives the messages to be displayed. The bug task begins when SCC_Audio_Trigger changes to 2331 and plays while AUX_Display2_RecieveFrom=1. When participant touches bug screen, begin steering disturbance to right by sending 1 to SCC_Steer_Input initiating push to left. Stop sending to SCC_Steer_Input after 10 sec.
END CONDITIONS	When the driver resumes stability and continues driving along the road and AUX_Display2_RecieveFrom=0.
CLEANUP	The speeding violation message is reengaged. 0 is sent to Reset AUX_Display_SendTo.
PERFORMANCE MEASURES	See Dependent Measures Table in section 1.2 of this document.

Table C1 Continued

BUG TASK 4-CURVE EVENT ID 2334	
RATIONALE	This is a primary distracter tasks that is associated with a planned road departure to the right while driving in a curve.
ROAD NETWORK REQUIREMENTS	Speed limit (in mph): 55 Overall length/distance needed to support event (in feet): 2,400 feet (1,200 to hear message, 1,200 to respond) Road type (lanes, surface): 2 driving lanes, paved surface, normal shoulders, ditch just beyond shoulder Intersection type: none Time of Day/Date: day
PREPARATION	The participant drives along a 2 lane rural road with narrow shoulders. There is assorted oncoming traffic at the rate of about 1 vehicle every 60 seconds The speed limit is 55 mph. The "Speeding Violation" message is suppressed during the time that the participant receives the message, so that he does not hear two messages at the same time.
START CONDITIONS	Driving along road and cross a road pad to trigger bug event.
ACTUAL EVENT	Event is located at the start of Curve 5 in Scenario 1, Curve 9 in Scenario 2, and Curve 12 in Scenario 3. The event ID, 2334, is written to LogStream 4. The appropriate event order (5, 9, 12) is written to LogStream 3. Create 3 additional bug task 1 Triggers: • Scenario 1: B2S1 Initial audio, B2S1 Delete initial audio, B2S1 Final Audio • Scenario 2: B3S2 Initial audio, B3S2 Delete initial audio, B3S2 Final Audio • Scenario 3: B4S3 Initial audio, B4S3 Delete initial audio, B4S3 Final Audio The event initiates when the appropriate value (1) is sent to the AUX_Display2_SendTo Cell. This cell transmits (via several steps) to the AUX computer in the cab and drives the messages to be displayed. The bug task begins when SCC_Audio_Trigger changes to 2331 and plays while AUX_Display2_RecieveFrom=1. When participant touches bug screen, begin steering disturbance to right by sending 1 to SCC_Steer_Input initiating push to left. Stop sending to SCC_Steer_Input after 10 sec.
END CONDITIONS	When the driver resumes stability and continues driving along the road and AUX_Display2_RecieveFrom=0.
CLEANUP	The speeding violation message is reengaged. 0 is sent to Reset AUX_Display_SendTo.
PERFORMANCE MEASURES	See Dependent Measures Table in section 1.2 of this document.

APPENDIX D: CD & TRIVIA TASKS SPECIFICACTIONS

Table D1: CD Task Specifications

CD TASKS: EVENT IDS 231, 232, 233, AND 234	
RATIONALE	These are secondary distracter tasks. They are not associated with a planned road departure. They are included to mask the importance of the planned lane departures associated with the primary distracter tasks.
ROAD NETWORK REQUIREMENTS	Speed limit (in mph): 55 Overall length/distance needed to support event (in feet): 2,400 feet (30 seconds - 80 feet/sec at 55 mph) Road type (lanes, surface): 2 driving lanes, paved surface, normal shoulders, ditch just beyond shoulder Intersection type: none Time of Day/Date: day
PREPARATION	The participant drives along a 2 lane rural road with narrow shoulders. There is assorted oncoming traffic at the rate of about 1 vehicle every 60 seconds The speed limit is 55 mph The "Speeding Violation" message is suppressed during the time that the participant receives the message, so that he does not hear two messages at the same time.
START CONDITIONS	Driving along road when driver crosses road pad trigger.
ACTUAL EVENT	The CD task message plays. This is caused by writing the appropriate ID # (231,232, 233, or 234) to the SCC_Audio_Trigger Cell. The event ID (231, 232, 233, or 234) is written to LogStream 4. The event order number (3, 6, 8, or 10) is written to LogStream 3.
END CONDITIONS	Participant returns CD to visor and returns to normal driving.
CLEANUP	The speeding violation message is reengaged.
PERFORMANCE MEASURES	This event has no specific measures associated with it.

Table D2: Trivia Task Specifications

Trivia Tasks: Event IDs 8981,8982, 8983 And 8984	
Rationale	The Trivia Tasks are secondary distracter tasks, and they are not associated with a planned road departure. They are included to mask the importance of the planned lane departures associated with the primary distracter tasks.
Road Network Requirements	Speed limit (in mph): 55 Overall length/distance needed to support event (in feet): 2,400 feet (1,200 to hear message, 1,200 to respond) Road type (lanes, surface): 2 driving lanes, paved surface, normal shoulders, ditch just beyond shoulder Intersection type: none Time of Day/Date: day
Preparation	The participant drives along a 2 lane rural road with narrow shoulders. There is assorted oncoming traffic at the rate of about 1 vehicle every 60 seconds The speed limit is 55 mph The "Speeding Violation" message is suppressed during the time that the participant receives the message, so that he does not hear two messages at the same time.
Start Conditions	Driving along road when driver crosses road pad trigger.
Actual Event	The Trivia message task plays. This is caused by writing the appropriate ID # (8981, 8982, 8983, or 8984) to the SCC_Audio_Trigger Cell. The event ID (8981, 8982, 8983, or 8984) is written to LogStream 4. The event order number (2, 4, 7, or 11) is written to LogStream 3. The appropriate value (1, 2, 3, or 5) is sent to the AUX_Display1_SendTo Cell. This determines which Trivia task to start.
End Conditions	Participant answers question and returns to normal driving.
Cleanup	The speeding violation message is reengaged.
Performance Measures	This event has no specific measures associated with it.

APPENDIX E: EMAIL WORDING

Subject: Participants invited for driving study

Want to test the newest in-vehicle technologies? We are looking for participants to take part in a driving simulation study at the National Advanced Driving Simulator. Teens 16-18 years old and Adults 35-55 years old are invited to participate in examining several new in vehicle technologies. You would be required to attend 1 daytime or evening visit up to 90 minutes in length. You will be paid for your time and effort. For more information, call 319-335-4719 or www.drivingstudies.com

Figure E1: Email Advertisement Wording

APPENDIX F: PHONE SCREENING

CWIM2 Phone Screening Procedures

For a participant to be eligible for a study they must meet **ALL** of the following criteria:

- Be able to participate when the study is scheduled
- Meet all inclusion criteria
- Pass the phone health screening questions

Overview

The purpose of this research study is to evaluate several new in-vehicle equipment designs and technologies.

- **Study Information, Time Commitment and Compensation**:

  Participating in this study involves one study visit that will last approximately 90 minutes. You will be required to come to University Research Park (formerly the Oakdale Campus) to participate.

  Participation involves signing a consent form and completion of several questionnaires before and after your study drive. You will receive instructions regarding driving the simulator cab and the study drive at your visit.

  Compensation for participating in this study will be $40 for a 90 minute study visit.

- **Willing to participate?**

  Are you still interested in participating?

  - If YES, continue with Inclusion Criteria
  - IF NO, ask if he/she would like us to keep him/her in our recruitment database for consideration of future participation.
    - IF NOT interested in future studies and wish to be removed from database
      - Make note regarding deletion
      - Reason if given

Figure F1: Phone Screening Procedures

Inclusion Criteria ~ General Driving Questions

Overview
Before this list of questions is administered, please communicate the following:

There are several criteria that must be met for participation in this study. I will need to ask you several questions to determine your eligibility.

If a subject fails to meet one of the following criteria, proceed to Closing.

1) **Do you possess a valid U.S. Drivers' License and have been a licensed driver for two years?** (Must answer YES)
(For 16-18 year olds, must possess a valid U.S. drivers' license or intermediate license and have been a licensed driver for at least 6 months.)

2) **Other than vision restrictions, is your drivers' license free of restrictions?** (Must answer YES)
(For 16-18 year olds, having intermediate license will not be considered a restriction on this question)

3) **Do you drive at least 10,000 miles per year?** (Must answer YES)
(For 16-18 year olds, no required inclusion of miles/year)

4) **Are you between the ages: 35-55?** (Must answer YES)
(For 16-18 year olds, are you between the ages of 16-18?)

5) **Are you able to drive without special equipment to help you drive such as pedal extensions, hand brake or throttle, spinner wheel knobs, seat cushion or booster seat?** (Must answer YES)

6) **Do you ever engage in behavior that may be distracting while driving such as: talking on your cell phone, sending or receiving text messages, eating, sending or receiving emails, or reading?**
(Must Answer YES)

7) **Would this be the first time you have you participated in any simulator driving study involving any new in-vehicle technologies?** (Must answer YES)

8) **Is your current vehicle FREE of new technologies such as Adaptive Cruise Control, Lane Departure Warnings, Collision Prevention Breaking, Blind Spot Detection, Adaptive Headlights, Night Vision Assistance, Rearview Cameras, or Rollover Prevention?** (Must answer YES)

General Inclusion Criteria is met
Proceed to Health Screening Questions Below

Figure F1 Continued

General Health Exclusion Criteria

Overview
Before administering this list of questions, please communicate the following: ➢ Because of pre-existing health conditions, some people are not eligible for participation in this study. I need to ask you some general health-related questions before you can be scheduled for a study session. ➢ **Your responses are voluntary and all answers are confidential.** ➢ You can refuse to answer any questions and only a record of your motion sickness susceptibility will be kept as part of this study. ➢ **No other responses will be kept.**

1) If the subject is female: ➢ **Are you, or is there any possibility that you are pregnant?**
Exclusion criteria: • If pregnant or there is any possibility of being pregnancy

2) Have you been diagnosed with a serious illness? ➢ If YES, is the condition still active? ➢ Are there any lingering effects? ➢ If YES, do you care to describe?
Exclusion criteria: • Cancer (receiving any radiation and/or chemotherapy treatment within last 6 months) • Crohn's disease • Hodgkin's disease • Parkinson's disease • Currently receiving any radiation and/or chemotherapy treatment

3) Do you have Diabetes? **NOTE**: Type II Diabetes accepted if controlled (medicated and under the supervision of physician)
Exclusion criteria: • Type I Diabetes - insulin dependent • Type II – **Uncontrolled** (see above)

4) Do you suffer from a heart condition such as disturbance of the heart rhythm or have you had a heart attack or a pacemaker implanted within the last 6 months? ➢ If YES, please describe?
Exclusion criteria: • History of ventricular flutter or fibrillation • Systole requiring cardio version (atrial fibrillation may be acceptable if heart rhythm is stable following medical treatment or pacemaker implants)

Figure F1 Continued

5) Have you ever suffered brain damage from a stroke, tumor, head injury, or infection?

- If YES, what are the resulting effects?
- Do you have an active tumor?
- Any visual loss, blurring or double vision?
- Any weakness, numbness, or funny feelings in the arms, legs or face?
- Any trouble swallowing or slurred speech?
- Any uncoordination or loss of control?
- Any trouble walking, thinking, remembering, talking, or understanding?

Exclusion criteria:

- A stroke within the past 6 months
- An active tumor
- Any symptoms still exist

6) Have you ever been diagnosed with seizures or epilepsy?

- If YES, when did your last seizure occur?

Exclusion criteria:

- A seizure within the past 12 months

7) Do you have Ménière's Disease or any inner ear, dizziness, vertigo, hearing, or balance problems?

- Wear hearing aides - full correction with hearing aides acceptable
- If YES, please describe.
- **Ménière's Disease** is a problem in the inner ear that affects hearing and balance. Symptoms can be low-pitched roaring in the ear (tinnitus), hearing loss, which may be permanent or temporary, and vertigo.
- **Vertigo** is a feeling that you or your surroundings are moving when there is no actual movement, described as a feeling of spinning or whirling and can be sensations of falling or tilting. It may be difficult to walk or stand and you may lose your balance and fall.

Exclusion criteria:

- Meniere's Disease
- Any recent history of inner ear, dizziness, vertigo, or balance problems

8) Do you currently have a sleep disorder such as sleep apnea, narcolepsy or Chronic Fatigue Syndrome?

- If YES, please describe.

Exclusion criteria:

- Untreated sleep apnea
- Narcolepsy
- Chronic Fatigue Syndrome

9) Do you have migraine or tension headaches that require you to take medication daily?

- If YES, please describe.

Exclusion criteria:

- Any narcotic medications

10) Do you currently have untreated depression, anxiety disorder, drug dependency, claustrophobia, or ADHD?

- If YES, please describe

Figure F1 Continued

Exclusion criteria:

- Untreated depression and ADHD
- Dependency or abuse of psychoactive drugs, illicit drugs, or alcohol
- Agoraphobia, hyperventilation, or anxiety attacks

11) Have you experienced any pain from neck or back injuries within the last year?

- ➢ If YES, is it current or chronic neck or back injury?

Exclusion criteria:

- Any current skeletal, muscular or neurological problems in neck or back regions
- Chronic neck and back pain
- Pinched nerves in neck or back
- Back surgery within last year

12) Are you currently taking any prescription or over the counter medications?

- ➢ If YES, what is the medication?
- ➢ Are there any warning labels on your medications, such as potential for drowsiness?

Exclusion criteria:

- Sedating medications or drowsiness label on medication UNLESS potential participant indicates they have been on the medication consistency for the last 6 months AND states they have NO drowsiness effects from this medication

13) Do you experience any kind of motion sickness?

- ➢ If YES, what were the conditions you experienced: when occurred (age), what mode of transportation, (boat, plane, train, car), and what was the intensity of your motion sickness?
- ➢ On a scale of 0 to 10, **how often** do you experience motion sickness with **0 = Never and 10 = Always**
- ➢ On a scale of 0 to 10, **how severe** are the symptoms when you experience motion sickness with **0 = Minimal and 10 = Incapacitated**

Exclusion criteria:

- One single mode of transportation where intensity is high and present
- More than 2 to 3 episodes for mode of transportation where intensity is moderate or above
- Severity and susceptibility scores rank high

14) Do you have any mobility issues that would make climbing down a short ladder or walking on a narrow walk way without assistance difficult for you to perform safely?

Exclusion criteria:

- none; make note on schedule to ensure extra staff on hand

15) Do you currently have any medical issues with your right shoulder that would make reaching into the backseat difficult?

Exclusion criteria:

- Any right shoulder ailment that would cause discomfort when turning and reaching towards backset

Proceed to Closing

Figure F1 Continued

Closing

MEETS ALL CRITERIA

Instructions:

- Refrain from drinking alcohol (subjects 35-55 years only).
- Please avoid taking any **NEW** prescription or over the counter drugs for the 24 hours preceding your driving session. If you do need to take a new medication 24 hours preceding your driving session, please call us. Ibuprofen, Tylenol, aspirin, and vitamins are acceptable to take prior to driving session.
- Bring Driver's License with you to appointment.
- If you use corrective lenses for driving please bring your glasses or contacts with you to the driving session. Bring reading glasses if needed to fill out questionnaires.
- We ask that cell phones and pagers be turned off or left home or in your car outside as they are not allowed while participating in the driving study.
- Request the following of all participants:
  - Wear flat shoes to drive in
  - No hats worn or gum chewing allowed while driving
  - Refrain from wearing artificial scents (perfume or cologne) as some staff allergic to scents
- You will be required to wear a seat belt while driving.
- TEENS – remind them they will not be able to participate without written conset from their parent/guardian
  - Remind them they need to know their Social Security Number in order for us to process the payment form.
- If your appointment is before 8am or after 5pm, the front door will be locked, therefore, please use the After Hours Call Box located at the right side on the front door. Press the call button and someone will let you in.
- Provide directions, explain where to park and ask them to check in at the front desk inside the main entrance.
- Inform participants to call **(319) 335-4285** if they are unable to make this appointment and need to reschedule as soon as possible (prefer 24 hour notice). Please leave a message if they receive voicemail and a staff member will return their call.

DOES NOT MEET CRITERIA:

- Inform participant that they may qualify for a future study and ask if they wish to remain in our database to be called for future studies.
- If participant is not in our database, ask if they would like to be considered for future driving research studies, if yes, fill out NADS database form.

Figure F1 Continued

APPENDIX G: INFORMED CONSENT

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID #: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

INFORMED CONSENT DOCUMENT

Project Title: **Driver Perceptions of New Vehicle Technology (DPNVT)**

Principal Investigator: **Timothy Brown**

Research Team Contact: **Nicole Hollopeter (319-335-4644)**

- If you are the parent/guardian of a child under 18 years old who is being invited to be in this study, the word "you" in this document refers to your child. You will be asked to read and sign this document to give permission for your child to participate.
- If you are a teenager reading this document because you are being invited to be in this study, the word "you" in this document refers to you. You will be asked to read and sign this document to indicate your willingness to participate.

This consent form describes the research study to help you decide if you want to participate. This form provides important information about what you will be asked to do during the study, about the risks and benefits of the study, and about your rights as a research subject.

- If you have any questions about or do not understand something in this form, you should ask the research team for more information.
- You should discuss your participation with anyone you choose such as family or friends.
- Do not agree to participate in this study unless the research team has answered your questions and you decide that you want to be part of this study.

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 16-17 and have held a valid driver's license for at least 6 months, you do not use any special equipment to help you drive and you are in good health.

The purpose of this research study is to evaluate several new in-vehicle equipment designs and technologies.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 200 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for approximately 90 minutes.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formerly the Oakdale Campus), study staff will verbally review this document with you, answer any

Page 1 of 7

Figure G1: Informed Consent for 16-17 Year Old Participants

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID #: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask for your birth date, gender, ethnicity, marital status, highest level of education completed, employment information, and participation in other driving studies. This questionnaire also asks you several health related questions including medication use and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle, and the tasks you may be asked to complete while driving. The tasks that you may be asked to complete involve catching a virtual bug and inserting a CD then finding a given track.

Prior to entering the simulator, temporary stickers will be applied to your face so that we may track your eye and head movements while you drive. These stickers are commerically manufactured and are the same type of stickers that are given to children at doctor's offices. The eye tracking cameras are mounted on the vehicle dashboard and will record your head and eye movements during the drive by following the movement of the stickers. If you are allergic to latex, please inform study staff and we will use temporary tattoos in place of stickers containing latex. If tattoos are used, a damp cloth will be pressed upon the tattoo that is applied to your face for about 30 seconds after which the damp cloth and tattoo backing will be removed leaving the tattoo. If tattoos are used instead of stickers, you will be asked to remove the tattoos before leaving, using your choice of several available over the counter cleansers. The stickers will be removed at the end of the study drives.

Then you will be escorted into the simulator and asked to drive for approximately 30 minutes. During the test drive you will experience a number of innovative vehicle design features and be asked to complete a number of tasks. After the drive, you will be asked to complete a questionnaire about how you feel.

You will be escorted back to the waiting room and asked to complete a questionnaire evaluating how real you viewed the simulator. Then you will be asked to complete a questionnaire about your driving experience and an additional questionnaire regarding your opinions about the new technology you experienced. A member of the research team will complete your payment form and you will be free to go.

You may skip any questions that you do not wish to answer on the questionnaire.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The system also contains video cameras that capture images of you while driving (e.g., driver's hand position on the steering wheel, forward road scene). These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected

Figure G1 Continued

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID #: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is then entered into the University of Iowa's Account Payable computer system. The payment form is shredded once your name, address, and social security number has been entered. The collection of your social security number is to be used only for payment of your time and effort for participating in this research study.

_____ I allow you to collect and use my social security number for the purposes outlined above.

_____ I do NOT allow you to collect or use my social security number for the purposes outlined above. (Initial your choice above)

WHAT ARE THE RISKS OF THIS STUDY?

You may experience one or more of the risks indicated below from being in this study. In addition to these, there may be other unknown risks, or risks that we did not anticipate, associated with being in this study.

The risk involving driving the simulator is possible discomfort associated with simulator disorientation. Some participants in driving simulator studies reported feeling uncomfortable during or after the simulator drive. These feelings were usually mild to moderate and consisted of slight uneasiness, warmth, or eyestrain. These effects typically last for only a short time, usually 10-15 minutes, after leaving the simulator. You may quit driving at any time if you experience any discomfort.

If you ask to quit driving as a result of discomfort, you will be allowed to quit at once. If you ask to quit driving due to discomfort, you will be escorted to a room, asked to sit and rest, and offered a beverage and snack. A trained staff member will determine if and when you will be allowed to leave. If you show few or no signs of discomfort, you will be able to go home or transportation will be arranged if you feel you are unable to drive home. If you experience anything other than slight effects, a follow-up call will be made to you 24 hours later to ensure you're not feeling ill effects.

In the rare event that normal exiting of the simulator is not available; you will need to exit the simulator through an alternative path. You will be assisted down a small ladder and escorted to a participant waiting room. This could pose a minimal risk if you have difficulty negotiating the ladder or walkway in the simulator bay.

An experimenter will be in the back seat of the simulator cab to ensure your safety while you drive.

Risks associated with latex stickers can be dryness, itching, burning, scaling, and lesions of the skin.

Risks associated with temporary tattoos can be mild skin irritation during removal.

Figure G1 Continued

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID#: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because information gained about how the public perceives and reacts to the vehicle innovations will contribute to improved vehicles in the future.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

You will be paid for being in this research study. You will need to provide your social security number (SSN) in order for us to pay you. You may choose to participate without being paid if you do not wish to provide your social security number (SSN) for this purpose. You may also need to provide your address if a check will be mailed to you. If your social security number is obtained for payment purposes only, it will not be retained for research purposes.

You will be paid $40 for your time. You will be paid with a check sent to your home address that you provided on the payment voucher.

You may quit the study at any time, however if you choose to quit before completion of the study your compensation will be pro-rated based on the length of time you participated. You will then be compensated $4 for every 9 minutes you participated.

WHO IS FUNDING THIS STUDY?

The National Highway Traffic Safety Administration is funding this research study. The University of Iowa is a subcontractor to Westat for this project. This means that the University of Iowa is receiving payments from the National Highway Traffic Safety Administration, through Westat, to support the activities that are required to conduct the study. No one on the research team will receive a direct payment or increase in salary from Westat or the National Highway Traffic Safety Administration for conducting this study.

WHAT ABOUT CONFIDENTIALITY?

We will keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people such as those indicated below may become aware of your participation in this study and may inspect and copy records pertaining to this research. Some of these records could contain information that personally identifies you.

- federal government regulatory agencies,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

Figure G1 Continued

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID #: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

To help protect your confidentiality, you will be assigned a study number which will be used instead of your name to identify all data collected for the study. The list linking your study number and name will be stored in a secure location and will be accessible only to the researchers at the University of Iowa. All records and data containing confidential information will be maintained in locked offices or on a secure password protected computer systems that are accessible to the researchers, the study sponsor, and its agents. It is possible that persons viewing the video data may be able to identify you. Study documents will be kept in a locked cabinet within a secure building that can only be entered by research personnel. After completion of analysis, all hard copies except the Informed Consent Documents will be scanned, placed on a CD and placed into the NADS archival room that has limited access by designated archival personnel. The original Informed Consent Documents will be stored in the NADS archival room that has limited access by designated archival personnel.

The **engineering data** collected and recorded in this study (including any performance scores based on these data) will be analyzed along with data gathered from other participants. These data may be publicly released in final reports or other publications or media for scientific (e.g., professional society meetings), regulatory (e.g., to assist in regulating devices), educational (e.g., educational campaigns for members of the general public), outreach (e.g., nationally televised programs highlighting traffic safety issues), legislative (e.g., data provided to the U.S. Congress to assist with law-making activities), or research purposes (e.g., comparison analyses with data from other studies). Engineering data may also be released individually or in summary with that of other participants, but will not be presented publicly in a way that permits personal identification, except when presented in conjunction with video data.

The **video data** (video image data recorded during your drive) recorded in this study includes your video-recorded likeness and all in-vehicle audio including your voice (and may include, in some views, superimposed performance information). Video and in-vehicle sounds will be used to examine your driving performance and other task performance while driving. Video image data (in continuous video or still formats) and associated audio data may be publicly released, either separately or in association with the appropriate engineering data for scientific, regulatory, educational, outreach, legislative, or research purposes (as noted above).

The **simulator data** is captured and stored on hard drives located within a limited access area of the NADS facility. Access to simulator data is controlled through permissions established on a per-study basis.

If we write a report or article about this study, or share the study data set with others, we typically describe the study results in a summarized manner so that you cannot be identified by name.

IS BEING IN THIS STUDY VOLUNTARY?

Taking part in this research study is completely voluntary. You may choose not to take part at all. If you decide to be in this study, you may stop participating at any time. If you decide not to be in this study, or if you stop participating at any time, you won't be penalized or lose any benefits for which you otherwise qualify.

Figure G1 Continued

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID#: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

Can Someone Else End my Participation in this Study?
Under certain circumstances, the researchers might decide to end your participation in this research study earlier than planned. This might happen if you fail to operate the research vehicle in accordance with the instructions provided, or if there are technical difficulties with the driving simulator.

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Nicole Hollopeter, 319-335-4644. If you experience a research-related injury, please contact Timothy Brown, 319-335-4785.

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 340 College of Medicine Administration Building, The University of Iowa, Iowa City, Iowa, 52242, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

This Informed Consent Document is not a contract. It is a written explanation of what will happen during the study if you decide to participate. You are not waiving any legal rights by signing this Informed Consent Document. Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 10/21/10.

______________________________ ______________________________
(Signature of Subject) (Date)

Parent/Guardian and Relationship to Subject:

______________________________ ______________________________
(Name - printed) (Relationship to Subject - printed)

Do not sign this form if today's date is on or after EXPIRATION DATE: 10/21/10.

______________________________ ______________________________
(Signature of Parent/Guardian) (Date)

Page 6 of 7

Figure G1 Continued

FOR IRB USE ONLY
APPROVED BY: IRB-02
IRB ID #: 200908788
APPROVAL DATE: 04/30/10
EXPIRATION DATE: 10/21/10

Check the method by which consent is being obtained:

□ Consent is being obtained by mail without a discussion between a research team member on this project and the parent of the subject. (Research team member does not sign this document)

□ Consent is being obtained in person or by mail after a discussion between a research team member listed at the top of this document and the parent of the subject. (Research team member signs below.)

Statement of Person Who Obtained Consent
(This line is only to be signed by a research team member after discussion with parent of the subject.)

I have discussed the above points with the subject or, where appropriate, with the subject's legally authorized representative. It is my opinion that the subject understands the risks, benefits, and procedures involved with participation in this research study.

____ ________________________________
(Signature of Person who Obtained Consent) (Date)

Figure G1 Continued

APPENDIX H: NADS DRIVING HISTORY QUESTIONNAIRE

Driving History Questionnaire – Teens

As part of this study, it is useful to collect information describing each participant. The following questions ask about you, your health, and your driving patterns. Please read each question carefully. If something is unclear, ask the researcher for help. Your participation is voluntary and you have the right to omit questions if you choose. Please remember that all of your answers will be kept confidential.

Background Information

1) What is your birth date? ______ / ______ / __________
Month Day Year

2) What age are you today? __________

3) What is your gender?
- ❒ Male
- ❒ Female

4) What is your marital status? (Check only one)
- ❒ Single, never married
- ❒ Married
- ❒ Domestic Partnership
- ❒ Separated or Divorced
- ❒ Widowed

5) What was your total household income last year? (Check only one)
- ❒ $0- $24,999
- ❒ $25,000- $29,999
- ❒ $30,000 - $34,999
- ❒ $35,000 - $39,999
- ❒ $40,000 - $49,999
- ❒ $50,000 - $59,999
- ❒ $60,000 - $69,999
- ❒ $70,000 - $79,999
- ❒ $80,000 - $89,999
- ❒ $90,000 - $99,999
- ❒ $100,000 or more

6) What is your present employment status? (Check only one)
- ❒ Unemployed
- ❒ Retired
- ❒ Work part-time
- ❒ Work full-time
- ❒ None of the above

7) What type of work do you do (e.g., teacher, homemaker)? ________________________________

8) How many children do you have? ________

Figure H1: NADS Driving History Questionnaire (Teens)

Date: ________

9) How many children under the age of 18 live at home? _______

10) How many children under the age of 14 live at home? _______

11) Of which ethnic origin(s) do you consider yourself? (Check all that apply)

- ❒ American Indian/Alaska Native
- ❒ Asian
- ❒ Black/African American
- ❒ Hispanic/Latino
- ❒ Native Hawaiian/Other Pacific Islander
- ❒ White/Caucasian
- ❒ Other

12) What is the highest level of education that you have completed? (Check only one)

- ❒ Primary School
- ❒ High School Diploma or equivalent
- ❒ Technical School or equivalent
- ❒ Some College or University
- ❒ Associate's Degree
- ❒ Bachelor's Degree
- ❒ Some Graduate or Professional School
- ❒ Graduate or Professional Degree

Driving Experience

13) How old were you when you started to drive? ________ years of age

14) For which of the following do you currently hold a valid driver's license within the United States? (Check all that apply)

	Vehicle Type	Year When FIRST Licensed (May be Approximate)
❒	Passenger Vehicle License	____ ____ ____ ____
❒	Commercial Truck License	____ ____ ____ ____
❒	Motorcycle License	____ ____ ____ ____
❒	Other: ______________________	____ ____ ____ ____
❒	Other: ______________________	____ ____ ____ ____

15) How often do you drive? (Check the most appropriate category)

- ❒ Less than once weekly
- ❒ At least once weekly
- ❒ At least once daily

Figure H1 Continued

Date: ___________

16) Approximately how many miles do you drive per year in each vehicle type, excluding miles driven for work-related activities? (Check only one for each vehicle)

Car	Motorcycle	Truck	Other: ___________
❒Do not drive	❒Do not drive	❒Do not drive	❒Do not drive
❒Under 2,000	❒Under 2,000	❒Under 2,000	❒Under 2,000
❒2,000 - 7,999	❒2,000 - 7,999	❒2,000 - 7,999	❒2,000 - 7,999
❒8,000 - 12,999	❒8,000 - 12,999	❒8,000 - 12,999	❒8,000 - 12,999
❒13,000 - 19,999	❒13,000 - 19,999	❒13,000 - 19,999	❒13,000 - 19,999
❒20,000 or more	❒20,000 or more	❒20,000 or more	❒20,000 or more

17) Is any driving you do work-related? (Check only one)

❒ No (Go to question # 18)
❒ Yes (please complete question 17a below)

17a) How many work-related miles do you drive per year? (Check only one)
❒ Under 2,000
❒ 2,000 - 7,999
❒ 8,000 - 12,999
❒ 13,000 - 19,999
❒ 20,000 or more

18) How frequently do you drive in the following environments? (Check only one for each environment)

	Never	Yearly	Monthly	Weekly	Daily
Residential	❒	❒	❒	❒	❒
Business District	❒	❒	❒	❒	❒
Rural Highway (e.g., Route 6)	❒	❒	❒	❒	❒
Interstate (e.g., Interstate 80)	❒	❒	❒	❒	❒
Gravel Roads	❒	❒	❒	❒	❒

19) What speed do you typically drive in a **residential area** when the speed limit is **25**?
__________mph

20) What speed do you typically drive in a **business district** when the speed limit is **35**?
________mph

21) What speed do you typically drive on a **rural highway** when the speed limit is **55**?
__________mph

22) What speed do you typically drive on the **Interstate** when the speed limit is **65?** __________mph

23) What speed do you typically drive on a **gravel road**? ___________mph

Figure H1 Continued

24) Have you ever had to participate in any driver improvement courses due to moving violations?

❒ No
❒ Yes (Please describe) ______________________________________

25) When driving, how frequently do you perform each of the following tasks/maneuvers?

(Check the most appropriate answer for each task/maneuver)

	Never	Rarely	Occasionally	Frequently	Always	Not Applicable
Change lanes on Interstate or freeway	❒	❒	❒	❒	❒	❒
Keep up with traffic in town	❒	❒	❒	❒	❒	❒
Keep up with traffic on two-lane highway	❒	❒	❒	❒	❒	❒
Keep up with traffic on Interstate or freeway	❒	❒	❒	❒	❒	❒
Pass other cars on Interstate or freeway	❒	❒	❒	❒	❒	❒
Exceed speed limit	❒	❒	❒	❒	❒	❒
Wear a safety belt	❒	❒	❒	❒	❒	❒
Make left turns at uncontrolled intersections	❒	❒	❒	❒	❒	❒

26) How comfortable do you feel when you drive in the following conditions or perform the following maneuvers? (Check the most appropriate answer for each condition)

	Very Uncomfortable	Slightly Uncomfortable	Slightly Comfortable	Very Comfortable	Not Applicable
Highway/freeway	❒	❒	❒	❒	❒
After drinking alcohol	❒	❒	❒	❒	❒
With children	❒	❒	❒	❒	❒
High-density traffic	❒	❒	❒	❒	❒
Passing other cars	❒	❒	❒	❒	❒
Changing lanes	❒	❒	❒	❒	❒
Making left turns at uncontrolled intersections	❒	❒	❒	❒	❒

Figure H1 Continued

27) How often do you engage in the following behaviors while driving?

	Never	Rarely	Occasionally	Frequently	Always
Talk on cell phone	❒	❒	❒	❒	❒
Read text or email	❒	❒	❒	❒	❒
Send text or email	❒	❒	❒	❒	❒
Eat	❒	❒	❒	❒	❒
Read	❒	❒	❒	❒	❒

Violations

28) Within the past five years, how many tickets have you received for the following? (Please check a response for each ticket)

	0	1	2	3+
Speeding	❒	❒	❒	❒
Going too slowly	❒	❒	❒	❒
Failure to yield right of way	❒	❒	❒	❒
Disobeying traffic lights	❒	❒	❒	❒
Disobeying traffic signs	❒	❒	❒	❒
Improper passing	❒	❒	❒	❒
Improper turning	❒	❒	❒	❒
Reckless driving	❒	❒	❒	❒
Following another car too closely	❒	❒	❒	❒
Operating While Intoxicated (OWI) or Driving Under the influence (DUI)	❒	❒	❒	❒
Other (please specify **type** and **frequency** of violation) ______________________________				

Accidents

29) In the past five years, how many times have you been the driver of a car involved in an accident?

❒ 0 (Go to question # 29 on page 7)
❒ 1
❒ 2
❒ 3
❒ 4 or more

Please provide the following information for each accident on the next page.

Figure H1 Continued

Accident 1

Was another vehicle involved?	❐ No	❐ Yes
Was a pedestrian involved?	❐ No	❐ Yes
Were you largely responsible for this accident?	❐ No	❐ Yes
Did you go to driver's rehabilitation?	❐ No	❐ Yes
Weather Condition: ______________________	Month/Year: __________________________	
Description:____		

Accident 2

Was another vehicle involved?	❐ No	❐ Yes
Was a pedestrian involved?	❐ No	❐ Yes
Were you largely responsible for this accident?	❐ No	❐ Yes
Did you go to driver's rehabilitation?	❐ No	❐ Yes
Weather Condition: ______________________	Month/Year: __________________________	
Description:____		

Accident 3

Was another vehicle involved?	❐ No	❐ Yes
Was a pedestrian involved?	❐ No	❐ Yes
Were you largely responsible for this accident?	❐ No	❐ Yes
Did you go to driver's rehabilitation?	❐ No	❐ Yes
Weather Condition: ______________________	Month/Year: __________________________	
Description:____		

6

Figure H1 Continued

Health Status

30) How often do you experience motion sickness? (Circle only one)

0	1	2	3	4	5	6	7	8	9	10
Never										Always

31) How severe are your symptoms when you experience motion sickness (Circle only one)

0	1	2	3	4	5	6	7	8	9	10
None										Severe

32) Have you taken any medication in the past 48 hours? (Check only one)

❐ No
❐ Yes (Please list all) ____

____

33) What is your normal bedtime (hour of the day)? ______________________________

Other Studies

34) Have you participated in other driving studies?

❐ No (End of questionnaire)
❐ Yes (please provide details for each study you have participated in below)

Study 1
What vehicle was used for this study? (Check only one)

❐ Actual car - only
❐ Another simulator - only
❐ National Advanced Driving Simulator (Motion Simulator)
❐ National Advanced Driving Simulator (Static Simulator)
❐ Both - actual car and another simulator
❐ Both - actual car and the National Advanced Driving Simulator (Motion Simulator)

Brief Description:
____

____

Figure H1 Continued

<u>Study 2</u>
What vehicle was used for this study? (Check only one)

❐ Actual car - only
❐ Another simulator - only
❐ National Advanced Driving Simulator (Motion Simulator)
❐ National Advanced Driving Simulator (Static Simulator)
❐ Both - actual car and another simulator
❐ Both - actual car and the National Advanced Driving Simulator (Motion Simulator)

Brief Description:
____

____

<u>Study 3</u>
What vehicle was used for this study? (Check only one)

❐ Actual car - only
❐ Another simulator - only
❐ National Advanced Driving Simulator (Motion Simulator)
❐ National Advanced Driving Simulator (Static Simulator)
❐ Both - actual car and another simulator
❐ Both - actual car and the National Advanced Driving Simulator (Motion Simulator)

Brief Description:
____

____

The End

Figure H1 Continued

APPENDIX I: TRAINING PRESENTATION

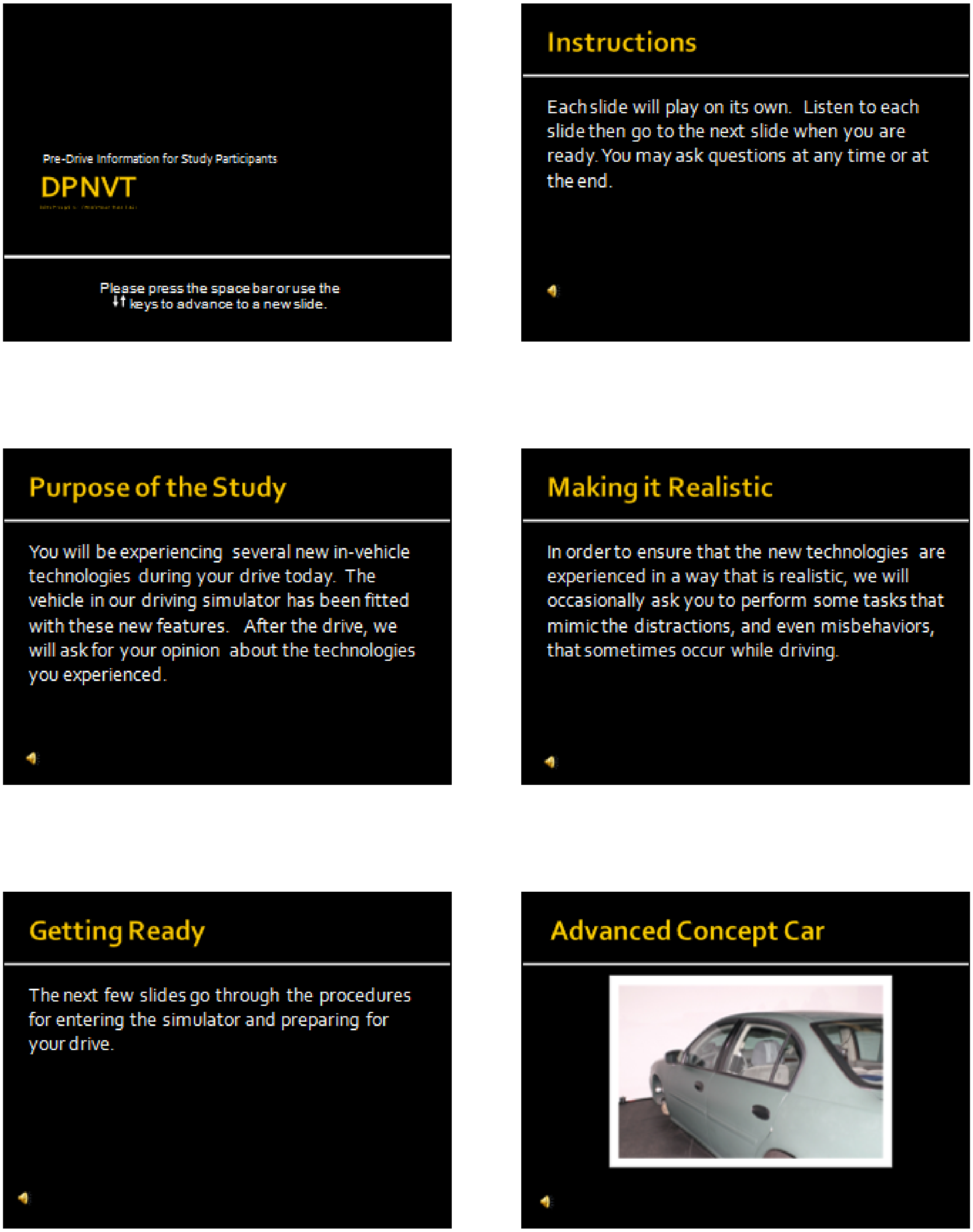
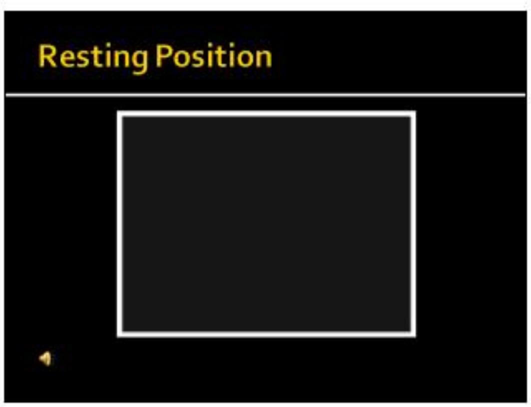


Figure I1: Training Presentation



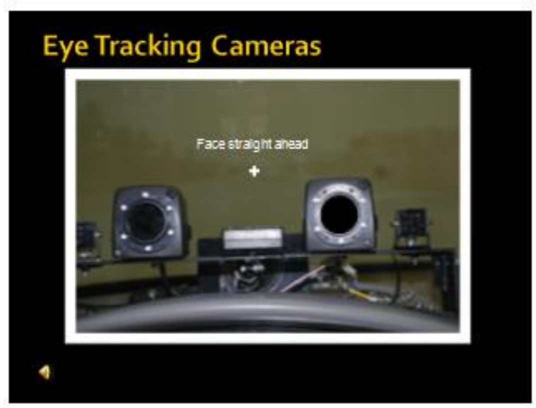
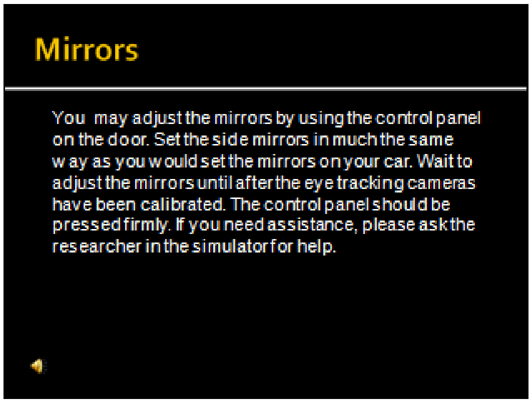
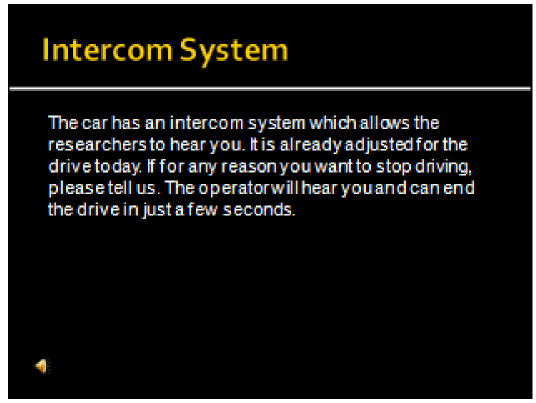
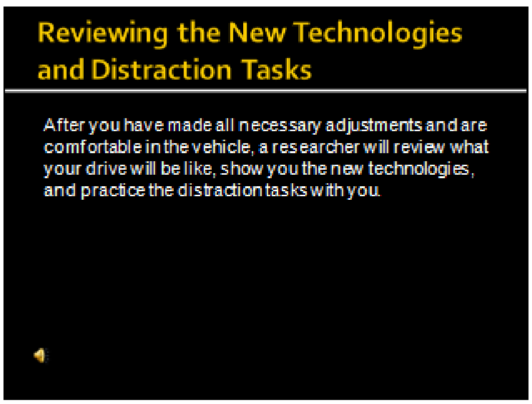
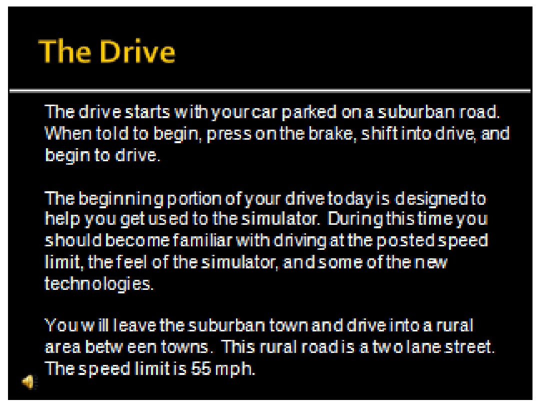


Figure I1 Continued









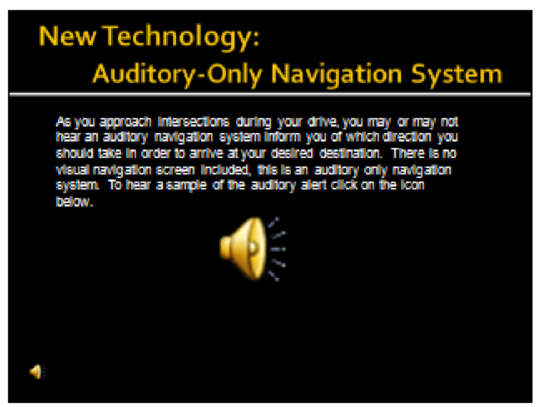
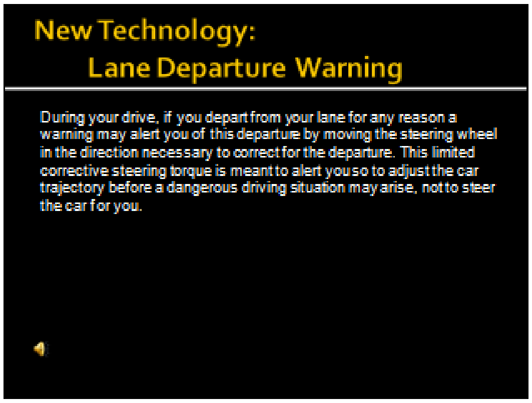


Figure I1 Continued



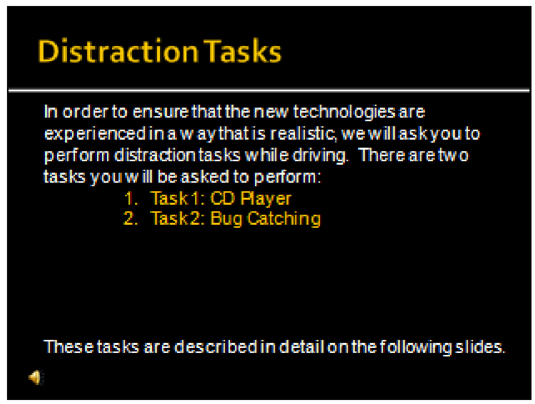


Figure I1 Continued

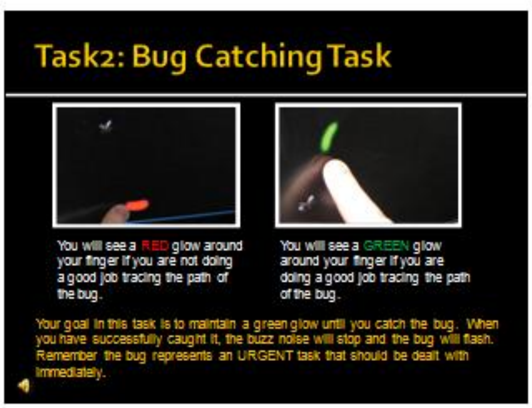
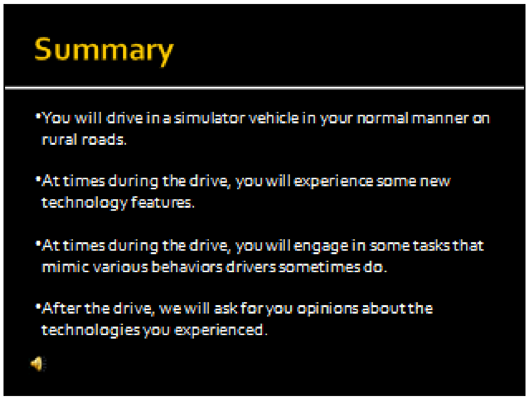


Figure I1 Continued



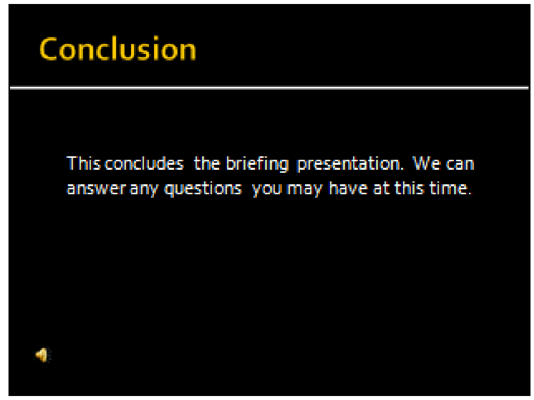


Figure I1 Continued

APPENDIX J: IN-CAB PROTOCOL

CWIM2 Main in-cab protocol (Auto Eye Tracking)

CAB ORIENTATION
[Participant has already viewed an introductory PPT about the study and the Malibu adjustments.]
[open car door] **(RAS): Please be seated and make the adjustments so you are in a comfortable driving position. If you need any help, please let me know.** *[Show mirror control panel but remind to adjust after eye tracking pictures]*
[Go to passenger side of cab.] [Resting position and seatbelt reminder]
(RAS): Before we move to the eye tracking procedures, we need to adjust the bug catching task screen so that you can reach all four corners *(help participant move screen so that is possible to touch all four corners of the screen).* **(RAS): We will now practice the Bug Catching Task. The bug catching task is considered an URGENT task that should be dealt with immediately. When you hear the buzz noise you should locate the bug on the screen, then place your finger on the screen and try to catch the bug by tracing it with your finger. It is important that you keep your finger on the screen until the buzz noise stops and the bug begins to flash which indicates that you caught the bug and the task is complete. Remember, if you see a red glow while you follow the bug, it indicates that you are NOT doing a good job whereas a green glow indicates that you are doing a good job. Please maintain the green glow and do not allow it to turn red. Do you have any questions?** *(answer questions or proceed)* **(RAS): Are you ready to practice?** *[If participant ready, control room initiates Bug Catching task.]* **After Practice: (RAS) Please remember that this is an URGENT task that should be dealt with immediately. You need to catch and kill the bug. Do your best to maintain the green glow.**
[Adjust Eye Tracking cameras here.]
(RAS): We are going to take the pictures for eye tracking so please look straight ahead at this time. *[when Eye Tracking is done, turn speaker OFF]*
As RAS reads point to the appropriate area of CD player.) **(RAS): This is the CD player that you will use when asked to select the appropriate track on a CD. You will use the track selection lever** *(demonstrate up and down)* **to advance to the appropriate track and the eject button.** *[RAS gets into backseat]* **(RAS): We will now practice the CD changing task. First I need you to look above at the CDs and list them for me.** *(pause to wait for participant to read CDs aloud)* **When you hear the prompt to select a track on a CD, select the appropriate CD from the visor, put it into the CD player, advance to the appropriate track, wait to hear the music, then eject the CD and return the CD to the appropriate slot on the visor. As soon as you hear the music start playing, it is important that eject the CD and return it to the visor. Do you have any questions?** *(answer questions or proceed)* **Are you ready to practice?** [If participant ready] **RAS: Please "advance to track 10 on the Elvis Presley CD."**

CWIM2 Main in-cab protocol (Auto Eye Tracking)

[RAS signals operator that after CD practice to move to starting position.]
[Complete Eye tracking and Trivia practice while simulator moving] **Sim Start: The simulator is moving towards its start position. During this time, you may hear rumbling and feel vibrations. This is perfectly normal. There are microphones in the cab so the Simulator Operator can hear you at all times. If, for any reason, you wish to stop driving, please let us know. The Operator can bring you to a stop in just a few seconds.**
(RAS) We will now proceed to the Trivia game practice. You will hear a sound indicating that there is a trivia question for you to answer. The computer will read you the trivia question and the answers will appear on this touch screen. *(point to screen)* **Touch the answer you feel is correct. You accumulate points for correct answers. I am able to provide you with the correct answers for the trivia game after the drive but not during your drive. Do you have any questions?** *(answer questions or proceed)* **Are you ready to practice the Trivia game?** *(if yes, control room initiates trivia game, if no, review procedure: question is heard, answer by pushing appropriate response on display)*
Study Drive **RAS: The drive starts with your car parked on a suburban road. When told to begin, press on the brake, shift into drive, and begin to drive. The first few minutes of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.** **You will leave the suburban town and drive onto a two-lane highway.** **(RAS): For data collection purposes, please keep communication with me to a minimum. I am here to answer questions or address concerns if needed. Please standby until you are told to begin** **(RAS): Do you have any questions? [answer questions, then proceed] [Cue operator that you are ready to proceed]** **AFTER FIRST BUG CATCHING TASK: Good Job. Please remember that this is an URGENT task that should be dealt with immediately.. You need to catch and kill the bug. Do your best to maintain the green glow.**
[RAS stays quiet but can give concise directions if asked, intervene for well being, or segue during any restarts]
[RAS works with Operator to identify correct restart if needed]
END DRIVE *file initiated from scenario [This is the end of the drive, please come to a complete stop and put the vehicle into park.]*
[RAS: Seatbelt fastened reminder.
[Administer Questionnaires]
[Exit Simulator]

Figure J1: In-Cab Protocol

APPENDIX K: DEBRIEF STATEMENT

Debriefing Statement
Thank you so much for participating in this study. Your participation was very valuable to us. We know you are very busy and appreciate the time you devoted to participating in this study.

There was some information about the study that we were unable to discuss with you prior to the study, because doing so may have impacted your actions and thus skewed the study results.

In this study, we were interested in understanding your reactions to different lane departure warnings while distracted. You were told that several new technologies were being tested; however, in reality, lane departures were simulated while you were distracted and data about your reaction to the warning modality was collected.

We hope this clarifies the purpose of the research, and the reason why we could not tell you all of the details about the study prior to your participation.

It is very important that you do not discuss this study with anyone else until the study is complete. Our efforts will be greatly compromised if participants come into the study knowing its true purpose and how their reactions are being examined. To this end, we would ask that you not discuss any of the details of the study until October 1, 2010.

Figure K1: Debrief Statement

APPENDIX L: SAMPLE PLOT OF EVENT

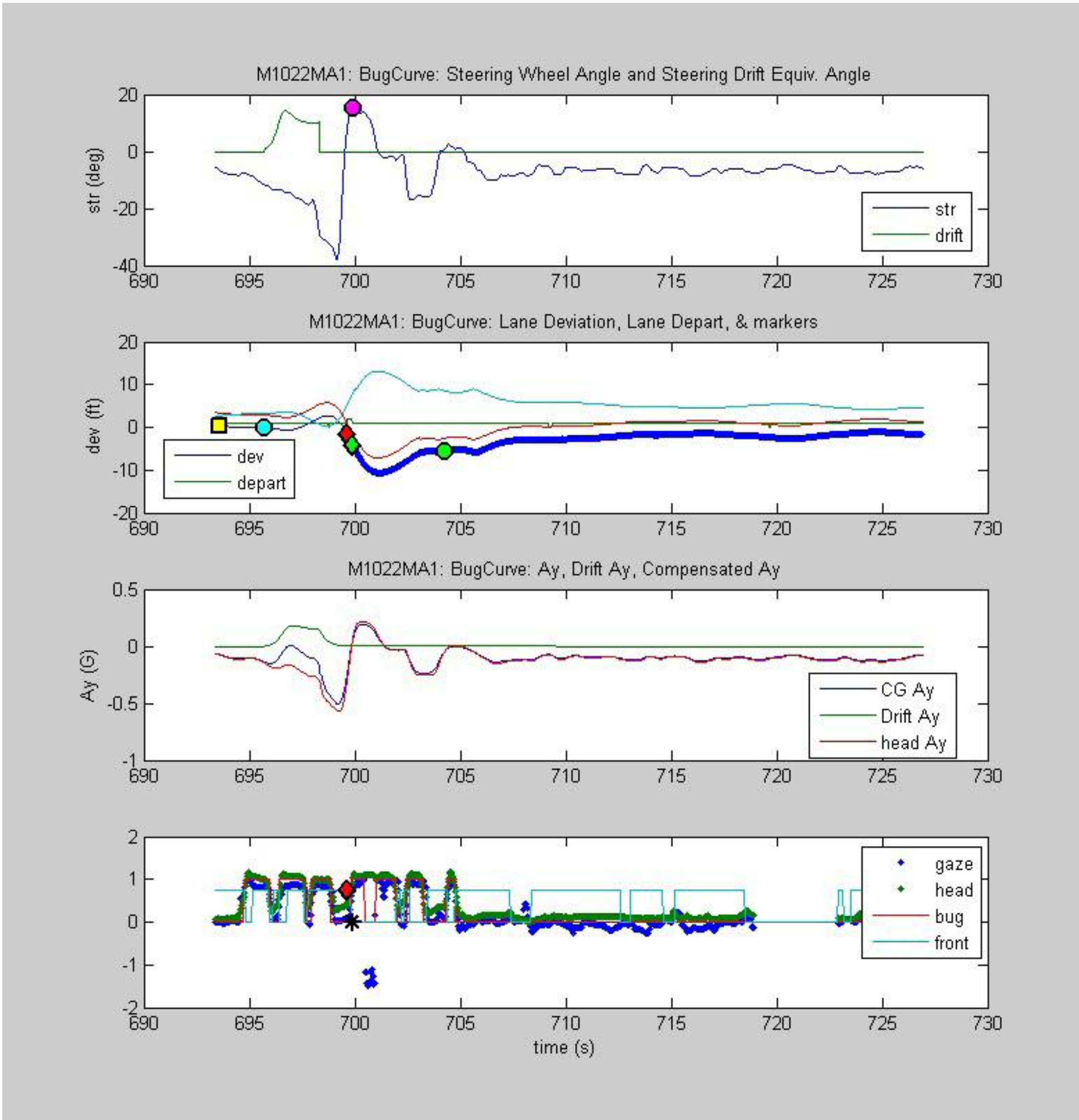


Figure L1: Sample Plot of Curve Event Showing Local Lateral Ay of -0.1

REFERENCES

Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis and Prevention,* 38, 215–24.

Beck, K.H., Shattuck, T., Raleigh, R., & Hartos, J. (2003). Does graduated licensing empower parents to place greater restrictions on their newly licensed teens' driving? *Health Education and Behavior,* 30, 695–708.

Bloomquist, G. (1986). A utility maximization model of driver traffic safety behavior. *Accident Analysis and Prevention*, 18, 371–385.

Bottom, C.G., & Ashworth, R. (1978). Factors affecting the variability of drivergap acceptance behavior. *Ergonomics*, 21, 721–734.

Braitmann K.A., Kirley, B.B., McCartt, A.T., & Chaudhary, N.K. (2008). Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research*, 39, 47-54.

Brown, I.D., & Groeger, J.A. (1988). Risk perception and decision making during the transition between novice and experienced driver status. *Ergonomics*, 31, 585–597.

Brown, Timothy L. (1994). "*An Examination of Active Control Intervention in Prevention of Run-Off-Road Accidents."* Masters Thesis. Department of Industrial Engineering, The University of Iowa.

Catchpole J., Macdonald W.A., & Bowland L. (1994). *Young Driver Research Program: The Influence of Age-related and Experience-Related Factors on Reported Driving Behavior and Crashes*. C.R. No.: 143. Victoria: Monash University Accident Research Centre.

Chen, L., Baker, S.P., Braver, E.R., & Li, G. (2000). Carrying passengers as a risk factor for crashes fatal to 16- and 17-year old drivers. *Journal of the American Medical Association*, 283, 1578–1582.

Chen, H.Y., Senserrick, T., Chang, H.Y., Ivers, R.Q., Martiniuk, A.L., Boufous, S., & Norton, R. (2010). Road Crash Trends for Young Drivers in New South Wales, Australia, from 1997 to 2007. *Traffic Injury Prevention*, 11, 1; 8-15.

Christie R. (2001). *The effectiveness of driver training as a road safety measure: a review of the literature*. Victoria, Australia: Royal Automobile Club of Victoria Ltd.

Cooper, P.J., Pinili, M., & Chen, W. (1995). An examination of the crash involvement rates of novice drivers aged 16 to 55. *Accident Analysis & Prevention*, 27, 89–104.

Deery, H.A. (1999). Hazard and risk perception among young novice drivers. *Journal of Safety Research*, 30, 225–236.

Engström I, Gregersen NP, Hernetkoski K, Keskinen E, & Nyberg A. (2003). Young novice drivers, driver education and training: literature review. Linköping, Sweden: Swedish National Road and Transport Research Institute.

Evans, L., & Wasielewski, P. (1983). Risky driving related to driver and vehicle characteristics. *Accident Analysis and Prevention*, 15, 121–136.

Ference, J.J., Szabo, S., & Najm, W.G. (2007). *Objective Test Scenarios for Integrated Vehicle-based Safety Systems*. Paper presented at the 20th International Technical Conference on the Enhanced Safety of Vehicles.

Ferguson, S.A. (2003). Other high-risk factors for young drivers—how graduated licensing does, doesn't, or could address them. *Journal of Safety Research*, 34, 71–77.

Ferguson S.A., Teoh, E.R., & McCartt, A.M. (2007). Progress in teenage crash risk during the last decade. *Journal of Safety Research*, 38, 37–45.

Ferguson, S.A., Leaf, W.A., Williams, A.F., & Preusser, D.F. (1996). Differences in young driver crash involvement in states with varying licensure practices. *Accident Analysis and Prevention*, 28, 171–180.

Fisher D., Pollatsek, A.P., & Pradhan, A. (2006). Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? *Injury Prevention*, 12, i25–i29.

Forsyth E., Maycock G., & Sexton B. (1995). *Cohort study of learner and novice drivers: Part 3, Accidents, offences and driving experience in the first three years of driving, Department of Transport TRL project report 111*. Transport Research Laboratory, Crowthorne, Berks.

Foss R.D., & Evenson, K.R. (1999). Effectiveness of graduated driver licensing in reducing motor vehicle crashes. *American Journal of Preventive Medicine*, 16, 47-56.

Foss, R.D., Feaganes, J.R., & Rodgman, E.A. (2001). Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. *Journal of the American Medical Association*, 286, 1588–1592.

Foss, R., & Goodwin, A. (2003). Enhancing the effectiveness of graduated licensing legislation. *Journal of Safety Research*, 34(1), 79-84.

Gillan J.S. (2006). Legislative advocacy is key to addressing teen driving deaths. *Injury Prevention*, 12, 44–48.

Gregersen, N.P. & Bjurulf, P. (1996). Young novice drivers own skill: Towards a model of their accident involvement. *Accident Analysis & Prevention*, 28(2), 229-241.

Gregersen, N.P. (1996). Young drivers' overestimation of their own skill–An experiment on the relation between training strategy and skill. *Accident Analysis and Prevention*, 28, 243–250.

Groeger, J.A., & Brown, I.D. (1989). Assessing one's own and others' driving ability: Influence of sex, age, and driving experience. *Accident Analysis and Prevention*, 21, 155–168.

Haggerty K.P., Fleming C.B., Catalano R.F., Harachi T.W., & Abbott R.D. (2006). Raising healthy children: Examining the impact of promoting healthy driving behavior within a social development intervention. *Prevention Science,* 7, 257–267.

Harrington, D.M., & McBride, R.S., (1970). Traffic violations by type, age, sex and marital status. *Accident Analysis and Prevention*, 2, 67-79.

Hartos J.L., Eitel P., & Simons-Morton B.G. (2002). Parenting practices and adolescent risky driving: a three month prospective study. *Health Education Behavior*, 29, 194–206.

Hartos, J.L., Eitel, P., & Simons-Morton, B.G. (2001). Do parent-imposed delayed licensure and restricted driving reduce risky driving behaviors among newly-licensed teens? *Prevention Science*, 2, 111–120.

Havard, J.D.J. (1979). Mortality from motor vehicle accidents in the 15-24 year age group. *World health statistics quarterly [0379-8070],* 32, 225-41.

Hedlund, J., & Compton, R. (2004). Graduated driver licensing research in2003 and beyond. *Journal of Safety Research*, 35, 5−11.

Hedlund, J. (2007) Novice teen driving: GDL and beyond. *Journal of Safety Research*, 38, 259–66.

Insurance Institute for Highway Safety. (2009). *Fatality Facts 2009: Teenagers*. Accessed March 2011, from http://www.iihs.org/research/fatality_facts_2009/teenagers.html

Janssen, W.H., & Tenkink, E. (1988). Considerations on speed selection and risk homeostasis in driving. *Accident Analysis and Prevention*, 20, 137–142.

Jonah, B.A., Thiessen, R., & Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. *Accident Analysis and Prevention*, 33, 679–684.

Karpf, R.S., & Williams, A.E. (1983). Teenage Drivers and Motor Vehicle Deaths. *Accident Analysis and Prevention*,15, 55-63.

Koneci, C., Ebbesen, E.B., & Koneci, D.K. (1976). Decision processes and risk taking in traffic: Driver response to the onset of yellow light. *Journal of Applied Psychology*, 6, 359–367.

Kuiken, M.J., & Twisk, D.A.M. (2001). *Safe driving and the training of calibration. Literature review, Report R-2001-29*. Leidschendam, The Netherlands: Institute for Road Safety Research (SWOV).

Laapotti, S., Keskinen, E., Hatakka, M., & Katila, A. (2001). Novice drivers accidents and violations - a failure on higher or lower hierarchical levels of driving behavior. *Accident Analysis and Prevention*, 33, 759−769.

Laberge-Nadeau C., Maag U., & Bourbeau R. (1992). The effects of age and experience on accidents with injuries: should the licensing age be raised? *Accident Analysis Prevention*, 24:107–116.

Lee, J.D. (2007). Technology and the teen driver. *Journal of Safety Research*, 38(2).

Litt I.F., & Steinerman P.R. (1981). Compliance with automotive safety devices among adolescents. *Journal of Pediatrics*, 99, 484-6.

Lonero L.P. (2008). Trends in driver education and training. *American Journal of Preventive Medicine*, 35:S316–S323.

Macdonald, W. (1994). *Young driver research program: A review of information on young driver crashes (Report CR 128)*. Canberra, Australia: Federal Office of Road Safety.

Mao, Y., Zhang, J., Robbins, G., Clarke, K., Lam, M., & Pickett, W. (1997). Factors affecting the severity of motor vehicle traffic crashes involving young drivers in Ontario. *Injury Prevention*, 3, 183–189.

Marchau, V.A.W.J., R.E.C.M. Van Der Heijden,& E.J.E. Molin, (2005). *Desirability of Advanced Driver Assistance from Road Safety Perspective: The Case of ISA.* Safety Science,43(1), 11-27.

Markush, R.E. et al. (1968). Motor vehicle accidents in United States (1906-1964). *Journal of the American Medical Association*, 203, 88-94.

Massie D.L., Campbell K.L., & Williams A.F. (1995). Traffic accident involvement rates by driver age and gender. *Accident Analysis and Prevention*, 27, 73-87.

Maycock G., Lockwood C.R., & Lester J.F. (1991). *The Accident Library of Car Drivers (Research Report 315)*. Transport and Road Research Laboratory, Crowthorne, Berkshire, England.

Mayhew, D.R., Donelson, A.C., Bierness, D.J., & Simpson, H.M. (1986). Youth, alcohol and relative risk of crash involvement. *Accident Analysis and Prevention*, 18, 273-287.

Mayhew, D.R., Simpson, H.M., Singhal, D., & Desmond, K. (2006). *Reducing the crash risk for young drivers*. Washington, DC: AAA Foundation for Traffic Safety.

Mayhew, D.R., & Simpson, H.M. (2002). The safety value of driver education and training. *Injury Prevention*, 8, 3−8.

Mayhew, D.R., Simpson, H.M., Williams, A.F., & Ferguson, S.A. (1998). Effectiveness and role of driver education and training in a graduated licensing system. *Journal of Public Health*, 19, 51–67.

Mayhew, D.R., Simpson, H.M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis and Prevention*, 35, 683−691.

McCartt, A.T., Hellinga, L.A., & Haire E.R. (2007). Age of licensure and monitoring teenagers' driving: survey of parents of novice teenage drivers. *Journal of Safety Research*, 38, 697-706.

McCartt, A.T., Mayhew, D.R., Braitman, K.A., Ferguson, S.A., & Simpson, H.M. (2009). *Effects of Age and Experience on Young Driver Crashes: Review of Recent Literature*. Insurance Institute for Highway Safety, Arlington, VA.

McCartt, A.T., Shabanova, V.I., & Leaf, W.A. (2003). Driving Experience, Crashes, and Traffic Citations of Teenage Beginning Drivers. *Accident Analysis and Prevention*, Vol 35, 311-320.

McGehee, D.V., Carney, C., Raby, M., Reyes, M.L., & Lee, J.D. (2007). Extending parental mentoring using an event-triggered video intervention in rural teen drivers. *Journal of Safety Research*, 38(2).

McGehee, D.V., Lee, J.D., Rakauskas, M.J., Ward, N.J., & Wilson, B. (2007). *The effect of lateral drift and curve speed warnings on driver response*. Paper presented at the 51st Annual Meeting of the Human Factors and Ergonomics Society.

McKenna, F.P., Waylen, A.E., & Burkes, M.E. (1998). *Male and female drivers: how different are they?* AA Foundation for Road Safety Research. The University of Reading. Hampshire, UK.

McKnight, A.J., & McKnight, A.S. (2003). Young novice drivers: careless or clueless? *Accident Analysis and Prevention*, 35, 921–925.

Najm, W.G., Koopmann, J., Boyle, L., & Smith, D. (2002). *Development of Test Scenarios for Off-Roadway Crash Countermeasures Based on Crash Statistics (No. DOT 809 505)*. Washington, DC: U.S. Department of Transportation.

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, 254-259.

Ontario Ministry of Transportation. (2007). *Ontario Road Safety Annual Report (ORSAR) 2007*. Accessed March 2011, from http://www.mto.gov.on.ca.

Organisation for Economic Co-operation and Development [OECD]. (2006). *Young drivers: The road to safety*. Paris: OECD publishing. Accessed March 2011, from www.cemt.org

Pelz, D.C., & Schuman, S.H. (1971). Are young drivers really more dangerous after controlling for exposure and experience? *Journal of Safety Research*, 3, 68-79.

Quimby, A.R. (1988). *In-car observation of unsafe driving actions (Report ARR 153)*. Berkshire, England: Transport and Road Research Laboratory.

Rivara, F.P., & Mueller, B.A. (1982). The epidemiology and causes of childhood injuries. *Journal of Social Issues*, 43, 13–31.

Sarkar, S., & Andreas, M. (2004). Acceptance of and engagement in risky driving behaviors by teenagers. *Adolescence*, 39, 687-700.

Schuman, S.H., Pelz, O.C., Westervelt, E H., & Quinn, 1. (1967). Young male drivers: Impulse expression, accidents and violations. *Journal of the American Medical Association*, 200, 1026-1030.

Senserrick, T.M. (2006). Reducing young driver road trauma: guidance and optimism for the future. *Injury Prevention*, 12, i56 –i60.

Senserrick, T.M. (2007). Recent developments in young driver education, training and licensing in Australia. *Journal of Safety Research*, 38, 237-244.

Shope, J.T., & Molnar, L.J. (2003). Graduated driver licensing in the United States: Evaluation results from the early programs. *Journal of Safety Research*, 34, 63-69.

Shope, J.T. (2006). Influences on youthful driving behavior and their potential for guiding interventions to reduce crashes. *Injury Prevention*, 12, 9–14.

Simons-Morton, B.G. (2002). Reducing young driver crash risk. *Injury Prevention*, 8, ii1 – ii2.

Simons-Morton, B.G., & Hartos, J.L. (2003). How well do parents manage young driver crash risks? *Journal of Safety Research*, 34, 91–7.

Simons-Morton, B. G., Lerner, N., Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers, *Accident Analysis & Prevention*, 37, 973-982,

Simons-Morton, B.G., Ouimet, M.C. (2006). Parent involvement in novice teen driving: a review of the literature. *Injury Prevention*, 12, 30–37.

Simons-Morton, B. (2007). Parent involvement in novice teen driving: Rationale, evidence of effects and potential for enhancing graduated driver licensing effectiveness. *Journal of Safety Research*, 38, 193-202.

Simons-Morton, B.G., Hartos, J.L., Leaf, W.A., & Preusser, D.F. (2006). Do recommended driving limits affect teen-reported traffic violations and crashes during the first 12 months of independent driving? *Traffic Injury Prevention*, 7, 238–47.

Simons-Morton, B.G., Hartos, J.L., & Beck, K.H.(2004). Increased parent limits on teen driving: Positive effects from a brief intervention administered at the motor vehicle administration. *Prevention Science*, 5, 101–111.

Simpson, H.M. & Mayhew, D.R. (1987). Youth and traffic accidents: causes and prevention. *Canadian Family Physician*, 33, 429-435.

Simons-Morton, B.G., Ouimet, M.C., & Catalano, R.F. (2008). Parenting and the Young Driver Problem. *American Journal of Preventive Medicine*.

Simpson, H.M. & Mayhew, D.R. (1992). *Reducing the Risks for New Drivers: A Graduated Licensing System for British Columbia*. Ministry of Attorney General, Victoria, British Columbia.

Stein, A.C., Allen, R.W. (1987). The effects of alcohol on driver decision making and risk taking. In *Noordzij PC, Roszbach R, eds. Alcohol, Drugs and Traffic Safety-T86*. (171–181). New York: Excerpta Medica.

Stewart, D.E., Sanderson, R.W. (1984). The measurement of risk on Canada's roads and highways. In *S. Yager, ed. Transport risk assessment*. Waterloo, Ontario: University of Waterloo Press.

Subramanian, R. (2006). *Motor vehicle traffic crashes as a leading cause of death in the United States, 2003 (No. DOT HS 810 568)*. Washington, DC: U.S. Department of Transportation.

Subramanian, R. (2005). *Motor vehicle traffic crashes as a leading cause of death in the United States, 2002 (No. DOT HS 809 831)*. Washington, DC: U.S. Department of Transportation.

Szabo, S., & Norcross, R. (2007). *Final Report: Objective Test Procedures for Road Departure Crash Warning Systems (No. DOT HS 810 829)*. Washington, DC: Department of Transportation.

Taylor, R.M. (1989). *Situational awareness rating technique (SART): The development of a tool for aircrew systems design*. Proceedings of the AGARD AMP Symposium on Situational Awareness in Aerospace Operations, CP478. Seuilly-sur Seine: NATO AGARD.

Twisk, D.A.M. & Stacey, C. (2007). Trends in risk of young drivers and countermeasures in European countries. *Journal of Safety Research*, 38, 245-257.

Ulmer, R.G., Williams, A.F., & Preusser, D.F. (1997). Crash involvements of 16-year-old drivers. *Journal of Safety Research*, 28, 97–103.

Vernick, J.S., Li, G., Ogaitis, S., MacKenzie, E.J., Baker, S.P., & Gielen, A.C. (1999). Effects of high-school driver education on motor vehicle crashes, violations, and licensure. *American Journal of Preventive Medicine*, 16, 40–46.

Vlakveld, W. (2004). *New policy proposals for novice drivers in the Netherlands*. Behavioural Research in Road Safety 2004, 14th Seminar. Department for Transport, London, UK.

Waller, P.F., Elliott, M.R., Shope, J.T., Raghunathhan, T.E., & Little, R.J. (2001). Changes in Young Adult Offense and Crash Patterns over Time. *Accident Analysis and Prevention*, 33, 117-128.

Waldeyer, R., & Gapp, C. (2009). *Mortality from road traffic injuries in children and young people*. European Environment and Helath Information System. (RPG2_Traf_E1).

Wasielewski, P. (1984). Speed as a measure of driver risk: Observed speed versus driver and vehicle characteristics. *Accident Analysis and Prevention*, 16, 89–103.

Wilde, G.J.S. (1986). Social interaction patterns in driver behavior: An introductory review. *Human Factors*, 18, 477–492.

Williams, A.F. (2003). Teenage drivers: patterns of risk. *Journal of Safety Research*, 34, 5–15.

Williams, A.F. (2005). Next steps for graduated licensing. *Traffic Injury Prevention*, 6, 199-201.

Williams, A. (2006). Young driver risk factors: successful and unsuccessful approaches for dealing with them and an agenda for the future. *Injury Prevention*. 12, i4–i8.

Williams, A.F., & Ferguson, S.A. (2004). Driver education renaissance? *Injury Prevention*, 10, 4-7.

Williams, A.F., & Ferguson, S.A. (2002). Rational for graduated licensing and risks it should address. *Injury Prevention*, 8(supplement II), 9-14.

Williams, A.F., Karpf, R.S., & Zador, P.L. (1983). Variations in minimum licensing age and fatal motor vehicle crashes. *American. Journal of. Public Health*, 73(12): 1401-1402.

Young, K. & Regan, M. (2007). Driver distraction: A review of the literature. In I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter & J.D. Irwin (Eds.), *Distracted Driving*. (pp. 379-405). Sydney, NSW: Australasian College of Road Safety.