THE EFFECT OF IN-VEHICLE WARNING SYSTEMS ON DRIVER RESPONSE IN WORK ZONES

by

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This research investigated the effectiveness of in-vehicle information technologies on driver behavior in work zones. In-vehicle information devices can increase driver awareness to an oncoming change in traffic flow and provide specific guidelines for driving speed requirements, lane merging strategies, or unexpected changes in the roadway (e.g., detours and lane shifts). The overall conditional effects for vehicle speed are significant; that is, both the audio and visual groups out performed the control group within the simulated work zone. Participants in audio group did outperform the visual group, not significantly though. The overall conditional effects for total time in violation are significant; that is, both the audio and visual groups out performed the control group. The test session results for Total Time in Violation were statistically significant, $F(2, 57) = 7.17$, $p < .01$. The strength of relationship between the warning messages and the Total Time in Violation with regular road signage, as assessed by $\eta^2$, was strong, the warning message factor accounting for 20% of the variance of the dependent variable.
My dissertation is dedicated to my dear mother and father whose support throughout my lifetime has been instrumental in my academic achievements.
ACKNOWLEDGMENTS

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CHAPTER 1: INTRODUCTION

Florida transportation trends indicate growing demands on transportation facilities and services, current system or supply of transportation, and impacts of the transportation system on our society.

- By 2025, Florida is expected to be the third most populated state, with over 20 million residents.
- Due to strong population growth, Florida Vehicles Miles of Travel (VMT) growth has outpaced national trends.
- While an aging population and lower growth rates suggest moderating growth in overall travel demand, continuing population and economic growth in Florida will, nevertheless, result in increasing demands on the transportation system.

In addition to these vectors, there are approximately 4.5 visitors to the state each year for every resident in the state (visitor growth rates have outpaced population growth rates). Likewise, truck travel on the Florida Intrastate has outpaced overall vehicle travel growth rates in the last few years. In general, Florida’s roadway system has been growing steadily, but not nearly as fast as the population or travel demand. There were 5,563 new lane miles of roadway added in 2002, and 2,483 new centerline miles. The Florida Intrastate Highway System (FIHS) is only 3% of the entire Florida roadway network and carries about 29% of all traffic and 64% of all truck traffic.

The National Highway System (NHS) encompasses approximately 160,000 miles (256,000 kilometers) of roadway supporting the nation’s economy, defense, and mobility (USDOT). Due
to growth, aging and road expansion driving through work zones is a common occurrence. The number of persons killed in motor vehicle crashes in work zones has risen from 872 in 1999 to 1,028 in 2003 (an average of 1,020 fatalities a year in the United States). Eighty-five percent of those killed in a work zone are drivers or occupants (remaining 15 percent were pedestrians and bicyclists). More than 40,000 people are injured each year as a result of motor vehicle crashes in work zones. Of the 1,028 work zone fatalities in 2003, two-hundred and thirty occurred in crashes involving large trucks. In 2003: approximately half of all fatal work zone crashes occurred during the day. More than two times as many fatal work zone crashes occurred on weekdays as on weekends. Fatal work zone crashes occurred most often in the summer and the fall. (Sources: Fatal crashes and fatalities - Fatality Analysis Reporting System (FARS) & Injuries - General Estimates System (GES)) Therefore, there is an important social mandate to improve work zone safety for the workers and traveling public.

Table 1: Fatalities in Work Zones (FARS, 2005)

<table>
<thead>
<tr>
<th>Year</th>
<th>Person Type</th>
<th>Occupant</th>
<th>Nonmotorist</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>737</td>
<td>135</td>
<td>872</td>
</tr>
<tr>
<td></td>
<td></td>
<td>84.5</td>
<td>15.5</td>
<td>100.0</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>837</td>
<td>169</td>
<td>1,026</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83.5</td>
<td>16.5</td>
<td>100.0</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>846</td>
<td>143</td>
<td>989</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85.5</td>
<td>14.5</td>
<td>100.0</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>1,031</td>
<td>155</td>
<td>1,186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86.9</td>
<td>13.1</td>
<td>100.0</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>903</td>
<td>125</td>
<td>1,028</td>
</tr>
<tr>
<td></td>
<td></td>
<td>87.8</td>
<td>12.2</td>
<td>100.0</td>
</tr>
<tr>
<td>1999-2003</td>
<td></td>
<td>4,374</td>
<td>727</td>
<td>5,101</td>
</tr>
</tbody>
</table>
**Rationale**

The primary goal of this research was to investigate the effectiveness of utilizing in-vehicle information technologies on driver behavior in work zones. In-vehicle information devices can increase driver awareness to an oncoming change in traffic flow and provide specific guidelines for driving speed requirements, lane merging strategies, or unexpected changes in the roadway (e.g., detours and lane shifts). Previous research efforts provide evidence that in-vehicle information technologies positively affect driver compliance and improve behavior, particularly in regarding to driving speed (Brookhuis & de Waard, 1999).

**Statement of the Problem**

A work zone is an area of a roadway with construction, maintenance, or utility work in progress and is typically marked by signs, channeling devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or traffic control device to the “end road work” sign or the last temporary traffic control device. Within work zones, construction, maintenance, and utility operations produce serious highway safety problems by affecting the normal traffic flow and generating unexpected conditions and serious traffic conflicts. A study conducted previously at the Human Factors Research Laboratory of the University of Minnesota DOT and sponsored by Minnesota DOT identified that the major cause of accidents in work zones was related to drivers exceeding safe speeds thereby reducing safety or increasing chances for fatalities or injuries (Stackhouse & Tan, 1998). Unfortunately, over the last five years, the number of persons killed in motor vehicle crashes in the US in work zones has risen from 872 in 1999 to 1,028 in 2003 (an average of 1,020 fatalities a year) as shown in Table 1 (FARS, 2005). Eighty-five percent of those killed in a work zone were drivers or occupants. More than 40,000
people were injured each year as a result of motor vehicle crashes in work zones (FARS, 2005). This trend is also apparent in Florida, as shown in Table 2.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CRASHES</th>
<th>FATALITIES</th>
<th>INJURIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>2,489</td>
<td>28</td>
<td>2,737</td>
</tr>
<tr>
<td>1998</td>
<td>2,163</td>
<td>24</td>
<td>2,340</td>
</tr>
<tr>
<td>1999</td>
<td>2,053</td>
<td>22</td>
<td>2,179</td>
</tr>
<tr>
<td>2000</td>
<td>2,045</td>
<td>22</td>
<td>2,133</td>
</tr>
<tr>
<td>2001</td>
<td>2,943</td>
<td>37</td>
<td>2,986</td>
</tr>
</tbody>
</table>

Crash rates increase about two-fold on highway segments under construction compared to crash rates on the same highway segments during previous years (Dodge & Levy 1977; Pigman & Agent 1990). To date, the typical way to inform drivers about an oncoming work zone is mostly comprised of road signs (e.g., Work Zone Ahead), flags, and traffic cones.

**Purpose of the Study**

The purpose of this study is to investigate in-vehicle presentation of audio and visual warning messages to enhance driver compliance to increase work zone safety. This will be investigated by using a simulated work-zone scenario in a driving simulator.

**Research Questions**

This investigation was conducted in order to examine whether the presence of an in-vehicle warning message (audio or visual) warning can increase compliance while driving through a
work zone. Secondly, to examine whether auditory warnings were more effective than visual messages.

**Significance of the Study**

While much work has been accomplished in the area pertaining to the in-vehicle presentation of audio and visual stimuli or a combination of these modalities there has been little or no research that looks at the delivery of in-vehicle audio and visual warning systems specifically to enhance safety in work zones. This research is novel as it investigates the delivery of warning messages utilizing the audio and visual modalities specifically for work zones. Likewise, the outcome of this investigation will enhance understanding and provide valuable information for drivers to encourage compliance to speed limits as well as increasing situational awareness.

**Methodology Issues**

While this author knows of no research investigating in-vehicle warning systems for work zone compliance there is a reasonable body of literature that discusses the use of warnings relating to in-vehicle navigation systems. However, within these bodies of research there are methodology issues that must be considered as well as understood in order to develop a baseline understanding in order to apply research findings to the research task at hand. A study by Burnett & Joyner (1997) highlights some of these disparities, different types of maps, the position of the maps within the vehicles, as well as the different memory demands. Also, past studies generally address one or two dependent variables advocating for a comprehensive approach calling for subjective measures throughout the driving task. In addition, prior studies have focused on mean glance duration and similar techniques which may neglect safety of a system.
CHAPTER 2: REVIEW OF LITERATURE

One of the most extensive studies of crash causes was the Indiana Tri-Level Study (Treat et. al., 1979). In this study driver errors were determined to be a definite or probable cause, or a severity-increasing factor, in 93% of crashes. In contrast, environmental factors were cited as certain or probable for 34% of the in-depth cases; vehicle factors were cited in 13%. These percentages total more than 100 because more than one causal or severity-increasing factor could be cited. However, the Tri-Level study found that human factors were the only cause of 57% of crashes. For success, the application of technology to crash avoidance must arise from an integrated understanding of the functional mechanisms of intervention of devices into the sequences of events, human errors in particular, that constitutes crash scenarios (Dingus, Jahns, Horowitz & Knipling, 1997).

**Modeling Driver Decision Making**

Research in the general area of Intelligent Transportation Systems (ITS) has given rise to important questions regarding drivers’ decisions making, which has always been fundamental to understanding vehicle traffic flow and to developing models for predicting urban traffic congestion. However, because of the complexities involved in modeling and understanding drivers’ decision making, standard urban transportation modeling has often focused on a more aggregate level: viewing traffic flow on highways as an observational unit to be studied. This has led to an entire body of literature that considers traffic flow analogous to fluid flow. This literature applies the principles of fluid flow, such as shock-wave analysis to the modeling of traffic flow. Such an approach is an attempt to replicate the product of individual driver decision
making and has been useful in many applications. However, in the presence of rapidly changing technology, such as that offered by ITS, the focus of research must be directed toward the primary decision-making unit—the driver—because the standard fluid-flow analogy is not likely to apply in an environment of vehicles containing possibly different levels of this technology in a single traffic stream (Mannering, 1997).

**Usability Evaluation for Intelligent Transportation**

To a large extent, the success of any information system, such as ITS, will depend on its usability or ability to be understood and conveniently employed by a user. Usability is a term with varied meanings, but it generally refers to the ease in which a system or its components can be used. Usability research can contribute too the development process in five ways: It can (a) inform the design process about people who ultimately will use the system in their daily lives, including their tasks, goals, background, environment, and culture; (b) validate assumptions about users’ preferences in design and requirements for documentation; (c) confirm good design decisions so that the developers can guard against inadvertently changing those decisions and can so capitalize on those ideas in future developments; (d) expose unexpected weaknesses in the user interface of which the developers may be unaware because of their familiarity with the product; and (e) resolve uncertainties when there are differing ideas within the team about the direction of the product or a feature (Spyridakis, Miller and Barfield, 1997).

**User Requirements for Intelligent Transportation System Design**

By consistently providing appropriately designed and delivered up-to-the-minute traffic information, one can improve short-term driver response to incidents and congestion and
produce long-term change in driver behavior that will increase the efficiency with which existing transportation facilities are used (Ng & Barfield, 1997). However, significant improvements in the level of congestion through delivery of traffic information can be achieved only if the mechanism for delivering that information is developed as an integrated system that is responsive to users’ needs and perspectives. Furthermore, targeting information for those motorists most likely to be affected does not mean that the same group will be targeted for all types of motorists’ information in all types of driving situations. This does mean, however, that a single integrated motorist information system must consist of carefully designed decisions of carefully studied and defined subgroups of receptive drivers (Ng & Barfield, 1997).

**Driving**

Operation of a vehicle is a learned skill which requires multitasking while processing information. The primary task of the driver is to effectively guide the vehicle, identify potential hazards, as well as correctly navigate to the desired destination (Seppelt & Wickens, 2003). First we might start with a concept of driving under normal conditions; Gibson & Crooks (1938) addressed this seemingly simple problem. As the authors point out, within the limits of the road there is an indefinite bounded field coined, “the field of safe travel”. In addition, at any point in time this field consists of the field of possible paths which the car may take unimpeded. Proceeding on this premise and understanding the research objectives we must ask ourselves how is this field of safe travel is affected when the driver is faced with situations such as a work zone. During normal driving the operator is expending minimal resources in the safe operation of his/her automobile. However, as the driving task increases in demand and complexity time sharing among input modalities, and in accordance, the appropriate output responses increase in
difficulty. With this in mind, as the participant drives through a work zone and encounters obstacles it is intuitive to acknowledge that time sharing between a visual warning system and a critical driving event may decrease the ability of the operator to maintain safety. The multitasking environment of driving requires simultaneous processing of information. The primary driving tasks include controlling the position of the vehicle, identifying potential hazards, and route management (Seppelt & Wickens, 2003). This type of investigation, at best, could be extremely dangerous if implemented in real world circumstances (i.e., the driving public). Fortunately, driving simulators are a powerful tool for examining performance in a realistic setting. That is, high fidelity and functional driving environments can be scripted to imitate real world scenario’s allowing for a range of quantitative as well as qualitative data to be collected (Klein, 1999).

**In-Vehicle Tasks**

A Technical Report by Seppelt and Wickens (2003) for General Motors examined multiple studies that assessed the factors that could moderate between auditory and visual in-vehicle information and its effect on the primary driving task and the processing of the information itself. Within this literature, Head-Up Display (HUD), in the driving display, and Head-Down Display (HDD), somewhere below the driving display were contrasted. Two interesting findings applicable to the positioning of the visual display are relevant to the research questions. First, where the HDD was more than 20 degrees from the line of sight there was a significant advantage of auditory over visual; however, there is no difference between the HUD and the HDD at 20 degrees or below (Wickens & Gosney, 2003).
In-Vehicle Warning Systems

Warnings are information presented to humans to communicate potential dangerous situations that might arise or are imminent (Braun & Silver, 1995). As compared to warnings, the function of alarms is to inform humans in the advent of exceeding system limits when approaching critical levels (Stanton & Baber, 1997). However, in both situations the warning message or alarm media should be user centered in order to effectively convey the information to the operator. As in-vehicle information systems as well as the technology that drives these systems becomes commonplace the design challenges become increasingly important.

Auditory and Visual Presentation of In-Vehicle Information

Next, let us examine the visual tasks involved with this experiment. First we have the primary task of driving. Next we have the work zone, which we shall label the hazardous event which further decrements the amount of visual attention allocated to the primary task. Thus, the time-sharing of the visual spatial tasks and their compatibility with the safe operation of the vehicle must be carefully considered in order not to overburden the visual system.

In a study by Lamble, Laasko and Summala (1999), in which attention demanding LED displays (4 to 8 seconds to comprehend) were positioned throughout the dashboard area of an automobile to investigate the driver’s ability to detect the approach of a decelerating car, found the most effective location was on top of the dashboard just to the right of the steering wheel (17 degrees from line of sight). While this may apply to emergency, taxis and police cars this is an uncommon placement for any visual display in a passenger car. Furthermore, while this certainly
could have implication for head down navigational displays it may in itself be irrelevant for a warning message that can be comprehended in under 1.5 seconds.

A study by Hughes and Cole (1986) suggests that 50% to 70% of visual demand is allocated to the primary driving task. Proceeding on this premise, in a study by Antin, Dingus, Hulse & Wierwille (1990) that compared the use of a moving navigational map system with a paper map suggests the visual demand did not exceed the remaining available capacity. The dependent measures for this conclusion were lane deviation, brake usage, accelerator movement, accidents, or near misses over the course of the experiment. Generally, due to the nature of vision, humans focus on a singular information source. Thus, attention monitoring of concurrent sources is can be considered serial. In contrast, audition encompasses characteristics that can compliment performance. (Folds & Gerth, 1994). When considering the visual modality, research suggests that focal and ambient vision are disparate resources (See Wickens, 2002: p.165):

- Supporting efficient time-sharing
- Characterized by qualitatively different brain structures
- Associated with qualitatively different types of information processing

A study by Spence and Driver (1997) reports that audio and visual information-processing do not occur independent of one another. The main conclusions from their investigation are 1) peoples response rate to visual stimuli is decremented when concurrent auditory information is to be processed 2) it is more efficient for people to receive audio and visual information from the same location 3) visuals signal are less effective than audio warnings at informing people to position.
However, in a study by Burnett & Joyner (1997), the plotted vehicle speed and glance duration, in general showed that longer glances were made towards a Head Up (HU) moving map display as compared to a Head Down (HD) moving map display reflecting that the driver may focus attention on the road as speeds increase. Likewise, while the amount of glance time decreased as speed of the vehicle increased the frequency of glances increased (although shorter in duration).

The audio modality is multi-directional, however, if the cue is set correctly it does allows for directional comprehension of in most environments (Folds & Gerth, 1994). In addition, according to Wickens (2002), dividing attention between the eye and the ear increases efficiency as compared to an auditory-auditory (AA) or a visual-visual (VV) presentation of information.

**Information Processing**

According to Brookhuis, Winsum, Heijer and Duynstee (1999), when presenting a visual signal the following components should be considered to avoid overload:

- Do the messages require more than 1.5 seconds to understand?
- Is it possible that the messages occur at unexpected moments, thus diverting attention from primary tasks?
- Are messages ambiguous or confusing?
- Do messages require elaborate decision making?

In a study by Victor, Harbluk & Engstrom (2005) which examined eye-movement measures to in-vehicle task difficulty as the visual task increases in difficulty the less time is spent looking at the road ahead (primary driving task). Of course this is an important finding and applicable to this research for the following reasons. First, how long does the discrete presentation of a visual
work zone warning message take to comprehend as well as respond to? This experiment also is investigating the continuous visual work zone message and one must examine the potential or possibility that this approach will cause the driver to spend more time than necessary glancing at the continuous warning message thus decrementing the primary task of safe driving.

When examining in-car tasks and relationship to driver performance the investigator should consider eccentricity as well as the mental load of the task. In fact, in the outcome of a study by Summala, Nieminen and Punto (1996) found that the visual angle from the driver’s line of sight mostly depends on the task itself. This brings me to the following point. The visual warning messages will be delivered via discrete or continuous presentation. The nature of the warning message is in itself very easy to comprehend. Sufficient scientific analysis is available to support both, the resource and multiple aspect of performance prediction, that is, the easier the task the less the interference and dissimilar task in structure interfere less, respectively (Wickens, 2002).

**Workload Measurement**

Workload is an important consideration in the operation of an automobile. First, one must establish a baseline workload requirement in order to investigate work zone task demand and the effects it renders on the drivers ability to allocate resources to the in-vehicle presentation of an audio, visual or combined audio/visual presentation while entering, driving through and exiting a work zone. Workload measurement is most important in order to assess which configuration provides optimal performance and efficiency while leaving the driver “residual capacity” to manage unrealized task demands (Yei Yu & Wickens, 1988).
Cognitive characteristics imply constraints on what information drivers require and how that information can best be displayed. Hence, the cognitive characteristics of drivers help to define information requirements and formats for display control. Furthermore, multiple factors such as ITS functional capabilities, environmental factors, and driver characteristics provide the context for driver interaction with ITS and play an important role in determining information that should be presented to the drivers (Lee & Kantowitz, 1997)
CHAPTER 3: EXPERIMENTAL

Participants

Sixty participants (27 males and 33 females) between the ages of 20 and 63 were recruited from Institute for Simulation and Training (IST) and University of Central Florida (UCF) by word of mouth and e-mail. All participants were required to have a valid driver’s license with at least three years of driving experience. The average age of the participants were 33 with the youngest at 20 years of age and the oldest at 63 years of age. The average year that all participants acquired their driver’s license was 1990.

Patrol Simulator

The Patrol Sim simulator is a high-fidelity, interactive training and research tool. The three-channel, three monitor immersive driving environment incorporates some of the most advanced technology on the market (GE Driver Development, 2003). This piece of equipment is central to the experiment. The scenarios for the orientation ride as well as the work zone scenarios were scripted and executed using this driving simulator.
Laboratory Virtual Instruments Engineering Workbench (LabVIEW) is a graphical programming language that is in wide use throughout industry, academia, and research labs throughout the world for data acquisition and instrument control software (National Instruments, 2005). For the purpose of this research LabVIEW will be interfaced with the GE Patrol Simulator for the express purpose of recording driver characteristics such as steering movement, speed, and triggering important events such as the delivery of audio and visual warning messages.

Hewlett Packard PDA

The HP Pocket PC with high-resolution is designed for fast, versatile mobile computing. A VGA color display and integrated wireless capabilities make the HP Pocket PC an ideal tool from the delivery of the visual presentation (Hewlett Packard). This device was mounted horizontally on
the center of the dash directly in the line of sight of the driver as illustrate in figure 12. In addition, the PDA was controlled via Blue Tooth wireless technologies.

**Sper Scientific Sound Meter 840029**

This sound meter offers a wide variety of measuring options including A and C decibel frequency weighting scales, fast or slow response, AC or DC output and peak function. The large display has a resolution of 0.1dB and also indicates low battery, and over or under load. It also covers 30 ~ 130dB in the A scale and 35 ~ 130dB in the C scale, with an accuracy of ±1.5dB. Can be easily calibrated using the internal oscillation system/. Has a fold out tripod stand and comes with carrying case, instructions, calibration tool, windscreen, and a 9 Volt battery. Weight: 10 oz (283 g). Dim: 81/2” x 31/8” x 13/8” (216 x 80 x 35mm).

**Radio Shack Speakers**

The audio warning message was delivered via a small speaker set mounted just below the PDA. The audio warning message was a recorded Microsoft .wav file using the experimenter’s voice that matched the text in the visual messages.

**Procedures**

Upon arrival participants were required to fill out an Informed Consent followed by a pre-simulation sickness questionnaire. Next the demographic survey, Driver Stress Inventory (DSI) and Driving Coping Questionnaire (DCQ) were administered. Subsequently, participants were given a scripted verbal overview of the simulator followed by a 3 to 5 minute orientation ride on the actual simulator used in the experiment. Next the participants were asked to fill out a NASA TLX (Workload Questionnaire) and then begin the actual test drive lasting on average 7 minutes
depending on how fast each participant drives. Upon completion of the test drive the participant
immediate filled out the post-simulation sickness questionnaire followed by the NASA TLX and
a short questionnaire on the audio and visual messages as well as normal hearing.

**Experiment**

The experiment is a between subjects study which consists of an audio, visual and control group.
The participants were required to ride through a simulated drive that included a work zone with
the total simulation lasting an average 7 minutes. All participants started at the same position, the
control group received regular road signage, the audio group received regular road signage plus
audio warning messages and the visual group received regular road signage plus visual warning
messages. Within the drive there was a stop sign, a work zone ahead sign, and a begin work zone
sign; once in the work zone if the driver traveled over 28 mph he or she would receive a
continuous visual or audio warning message until compliance; and, in addition, another stop sign
and finally after exiting the work zone they were asked to pull over to the right and with the
completion of some follow-up questionnaires the experiment was concluded.

**Scenario**

Figure 2 represents the starting position for all participants.
Figure 2: Participants Starting Point

Figure 3 represents the trigger point for the audio and visual warning messages. The Road Construction Ahead sign seen in the figure below was present for the control, audio, and visual groups. Pertaining to the audio and visual group, when the participant passed the road construction ahead sign the appropriate audio or visual warning message was initiated and presented accordingly.
Figure 3: Road Construction Ahead

Figure 4 represents the beginning of the work zone. The arrow is an animated signal that moves from right to left.

Figure 4: Beginning of Work Zone
Figure 5 is also at the beginning of the work zone. Please notice that the speed limit is posted for the control, audio, and visual groups. Also, please notice the police car to the left as often seen in today’s work zones.

Figure 5: Beginning of Work Zone

Figure 6 also shows the beginning of the work zone.

Figure 6: Beginning of Work Zone
Figure 7 also shows the various objects at the beginning of the work zone.

Figure 7: Beginning of Work Zone

Figure 8 illustrates participant position approximately six seconds into the work zone.

Figure 8: People
Figure 9 is the position of the owncab approximately one-third through the work zone.

Figure 9: Workman

Figure 10 is the participant’s position approximately two-thirds through the simulated drive. The participants showed little response to this potentially hazardous event.

Figure 10: Forklift
Figure 11 represents the end of the work zone. After the last cone drivers were asked to pull over to the right which ended the driving portion of the experiment.

![Figure 11: End of Work Zone](image)

**Discrete Warning Messages**

The discrete warning message is only applicable to the visual and audio groups. The visual message was delivered via line of sight and is illustrated in the figure below. Both a visual and audio discrete message were delivered at the work zone ahead sign and the begin work zone sign. Please note that the audio and visual warning messages were confined to their separate experimental conditions. Also, the visual message was delivered at approximately 18 degrees from the line of sight.
The discrete visual warning messages are illustrated in Figures 13 & 14. The discrete audio warning message matched the text that was displayed to the participants in the visual warning message. At this point, it is important to describe how the discrete messages were triggered. When the owncab (participant vehicle) crossed a certain pixel range in the simulation it triggered a response which was sent to the PDA or speaker system. The pixel range used was 25 pixels in width and 25 pixels in length (using the owncab position via the operator’s console). This was set and the same for all participants. The intensity of the audio warning message was calibrated at 60 decibels for each participant in the audio group using a handheld decibel meter which is similar to conversational speech.
Figure 13: Visual message at Work Zone Ahead Sign

Figure 14: Visual message at Begin Work Zone Ahead Sign
Visual and Audio Continuous Warning Message

Once the driver passes the begin work zone sign he or she is in the work zone and if their speed increases to or above 28 mph which is three miles over the posted speed limit for the work zone the audio or visual warning message is triggered and remains on until the driver is in compliance. The visual continuous warning message is illustrated in Figure 15 and was presented to the driver in an on/off fashion. The frequency of the on/off was at 0.5 second on and 0.5 second off and remained until compliance. The audio message is matched to the text displayed within the visual message (slow down) which is also delivered in an on/off 0.5 second duration presentation to the participants.

![Figure 15: Slow Down](image-url)
The audio warning message was delivered via the small speaker set mounted just below the PDA.

Compliance

Compliance (obeying the work zone posted speed) itself answers the research questions proposed for the topic of this dissertation. A statistical analysis was conducted to evaluate the relationship between the warning messages and compliance. The independent variable, the warning message factor, includes three levels: control, audio, and visual. The dependent variable is driver compliance and will be measured by total time in violation which consists of many sub-parts. Compliance is only relative to the work zone. Once the participants enter the work zone the warning message is activated if the driver reaches the speed of 28 mph. The subparts of compliance are as follows:

Total Time in Violation within the Work Zone

- Total time of each violation
- Mean Total time of each violation
- Mean Speed of each violation
- Mean Speed of all violations
CHAPTER 4: EXPERIMENTAL RESULTS

The first section examines homogeneity of the three groups through their personality characteristics (DSI and DCQ), and pre-task workload estimates and simulation sickness estimates. Furthermore, the following, illustrates the results from the subsequent instruments in order to establish that the control, audio and visual group characteristics are virtually the same on several points of attribute. The first questionnaire includes information on the visual and audio cues as well as hearing questions. Next, we discuss the driving stress inventory questionnaire (DSI) that looks at aggression, dislike of driving, hazard monitoring, fatigue proneness and thrill seeking; followed by the driving coping questionnaire which examines confrontive coping, task focus, emotion focus, reappraisal, and avoidance. And finally the NASA TLX and simulation sickness examines whether there are any anomalies within the groups that might adversely affect the findings. The main result section examines descriptive statistics relating to total time in violation vs. total time in work zone, mean time of violations, mean speed of violations, and within work zone trends. In addition, this section discusses the outcome of the analysis of variance and post hoc statistical analysis.

Homogeneity of Groups

The following figure results from a survey found in Appendix I and served as a follow-up questionnaire for the audio and visual warning messages. All participants reported no corrective hearing device, no hearing loss, and normal hearing. This is important because the audio warning
message was calibrated using a Db meter to a normal conversation loudness so all participants received the same intensity of audio.

![Figure 16: Warning Messages](image)

The following figure is the result of the Driving Stress Inventory (DSI), (Matthews, Desmond, Joyner, Carcary and Gilliland, 1996) which measures several driving characteristics as illustrated below. All groups means were close on all five attributes, that is, there were no significance differences between groups and shows that all groups were evenly distributed. While thrill seeking in its self is eye-catching there was no significant effect on the driver’s behavior within the work zone.
The following figure is the result of the Driving Coping Questionnaire (DCQ) (Matthews, Desmond, Joyner, Carcary and Gilliland, 1996) which measures several driving characteristics as illustrated below. All groups were close on all five attributes, that is, there were no significance differences between groups on individual measures and shows that all groups were evenly distributed.
The following figure illustrates the result of the NASA TLX (Hart & Staveland, 1988) and measures several components of work load. This instrument was administered pretest-posttest. While the audio and visual groups remained virtually unchanged there was a slight movement on physical demand and effort in the control group. While this is noteworthy, it did not yield any significance in its relationship to the main research questions.
Figure 19: National Aeronautical Space Administration Task Load Index (NASA-TLX)
The following figure illustrates the pre-test post-test simulation sickness results for the experiment which were significant (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Questionnaires can be found in Appendix E. All post-test scores were within acceptable range for simulation sickness. A pre-test post-test analysis was conducted and can be found in Appendix K.

![Simulation Sickness Graph](image)

Figure 20: Simulation Sickness

The following figures illustrates acceleration, braking, lane position, steering and speed of the control, audio and visual groups from the starting point of the simulation up to work zone ahead sign. Figure 21 addresses acceleration and braking.
Figure 21: Acceleration and Braking

Figure 22 through 24 represents the mean lane position, steering and speed of all participants from the beginning of the scenario up to the Work Zone Ahead sign.
Figure 22: Lane Position

Figure 23: Steering Movement
The following figures the differences between groups pertaining to acceleration, braking, lane position, steering and speed after the work zone ahead sign up to the begin work zone sign. All groups show similar behavior on all categories.
Figure 25: Acceleration and Braking

Figure 26: Lane Position
Figure 27: Steering Wheel Movement

Figure 28: Velocity
Group Parameters: Within Work Zone

The following figures illustrate group parameters within the work zone. While there is virtually no difference between groups pertaining to acceleration, braking, lane position, and steering the control group has now exceeded the audio group by five mph and the visual group by four mph.

![Group Parameters (Within WZ)](image)

**Figure 29: Acceleration and Braking**
Figure 30: Lane Position

Figure 31: Steering Wheel Movement
Figure 32: Velocity

Results

Figure 33 describes total time in violation in units of seconds as compared to total time in work zone. Notice that the audio group spent the longest time in the work zone (186.8 seconds) and the shortest time in violation (12.6 seconds). In addition, the audio group spent 12.6 seconds in violation as compared to the visual group at 32.3 seconds and the control group at 70.6 seconds.
**Figure 33: Total Time in Violation**

Figure 34 illustrates the mean time of violations in seconds. The audio group responded at 3.33 seconds followed by the visual group at 8.95 seconds and the control group at 25.62 seconds.
Figure 35 illustrates the mean speed of the violations in mph (Violations refers to the number of times the participant exceeded 28 mph). The mean for the audio group is 30.97 mph followed by the visual group at 32.40 mph followed by the control group at 33.96 mph.

![Mean Speed of Violations](chart)

Figure 36 illustrates 110 seconds of the drive beginning at the start of the work zone. 110 seconds is the shortest amount of time out of all 60 participants that it took to drive the entire work zone.
Figure 37 illustrates the first 22 seconds within the work zone for the control audio and visual groups. Each trend line represents the mean of 20 participants. The audio group responds within approximately 6 seconds while the visual group takes 22 seconds to respond.
The quantitative results for the factorial analyses yielded the following results. The overall conditional effects for vehicle speed are significant; that is, both the audio and visual groups outperformed the control group. Participants in audio group did outperform the visual group, not significantly though. Descriptive statistics are illustrated in the table below.

**Dependent Measure: Speed**
Table 3: Descriptive Statistics-Speed

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>29.9345</td>
<td>7.14841</td>
<td>20</td>
</tr>
<tr>
<td>Audio</td>
<td>24.3225</td>
<td>1.33279</td>
<td>20</td>
</tr>
<tr>
<td>Visual</td>
<td>25.8840</td>
<td>4.16720</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>26.7137</td>
<td>5.32055</td>
<td>60</td>
</tr>
</tbody>
</table>

The test session results for Total Time in Violation were statistically significant, \( F(2, 57) = 7.17, \) \( p < .01. \) The strength of relationship between the warning messages and the Total Time in Violation with regular road signage, as assessed by \( \eta^2 \), was strong, the warning message factor accounting for 20% of the variance of the dependent variable.

Follow-up tests were conducted to evaluate pairwise differences among the means. Because the variances among the three groups ranged from 1.78 to 51.01, we chose not to assume that variances were homogenous and conducted post hoc comparisons with the use of the Dunnett’s C test, a test that does not assume equal variances among the three groups. There was a significant difference between the groups that received the audio and visual warning messages as compared to the control (regular road signage), but no significant difference between the audio and visual groups, nevertheless, the audio group did out perform the visual group for the first 22 seconds. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 4.
Compliance: Total Time in Violation

The quantitative results for the factorial analyses yielded the following results. The overall conditional effects for total time in violation are significant; that is, both the audio and visual groups outperformed the control group. Participants in audio group did outperform the visual group, not significantly though. Descriptive statistics are illustrated in the table below.

Table 5: Total Time in Violation

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>70.6000</td>
<td>42.59528</td>
<td>20</td>
</tr>
<tr>
<td>Audio</td>
<td>12.6000</td>
<td>10.69383</td>
<td>20</td>
</tr>
<tr>
<td>Visual</td>
<td>32.3000</td>
<td>39.21882</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>38.5000</td>
<td>41.30560</td>
<td>60</td>
</tr>
</tbody>
</table>
The test session results for Total Time in Violation were statistically significant, $F(2, 57) = 15.06$, $p < .01$. The strength of relationship between the warning messages and the Total Time in Violation with regular road signage, as assessed by $\eta^2$, was strong, the warning message factor accounting for 35% of the variance of the dependent variable.

Follow-up tests were conducted to evaluate pairwise differences among the means. Because the variances among the three groups ranged from 114.28 to 1814.76, we chose not to assume that variances were homogenous and conducted post hoc comparisons with the use of the Dunnett’s C test, a test that does not assume equal variances among the three groups. There was a significant difference between the groups that received the audio and visual warning messages as compared to the control (regular road signage), but no significant difference between the audio and visual groups, nevertheless, the audio group did out perform the visual group overall. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 6.

**Table 6: Post hoc comparison**

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Audio</td>
<td>5.6120*</td>
<td>1.62598</td>
<td>1.4813</td>
<td>9.7427</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>4.0505</td>
<td>1.85021</td>
<td>-6.499</td>
<td>8.7509</td>
<td></td>
</tr>
<tr>
<td>Audio</td>
<td>Control</td>
<td>-5.6120*</td>
<td>1.62598</td>
<td>-9.7427</td>
<td>-1.4813</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>-1.5615</td>
<td>.97831</td>
<td>-4.0469</td>
<td>.9239</td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>Control</td>
<td>-4.0505</td>
<td>1.85021</td>
<td>-8.7509</td>
<td>.6499</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audio</td>
<td>1.5615</td>
<td>.97831</td>
<td>-.9239</td>
<td>4.0469</td>
<td></td>
</tr>
</tbody>
</table>

Based on observed means.

* The mean difference is significant at the .05 level.
CHAPTER 5: DISCUSSION

Discussion of Results

The primary goal of this project is to provide possible design recommendations for safe delivery of warning messages within work zones by reducing a driver’s speed through a work zone. In the multi-tasking environment of driving it is assumed that the driver will intuitively keep the primary task above all other tasks (Wickens & Gosney, 2003). Thus, all other tasks become secondary in importance. The major findings are as follows:

- Participants in the audio condition took six seconds to respond
- Participants in the visual condition took twenty-two seconds to respond
- Participants in the control group slowed at the beginning of the work zone, however, they violated the speed limit for the entire work zone

While the findings are interesting and certainly a solid starting point for future research the reader must consider that the work zone may or may not be typical of what a driver may find in a work zone. There are many configurations of work zones requiring different levels of demand on the visual system. With this in mind, the visual demand may fluctuate from work zone situation to work zone situation. While the results show that both the audio and visual groups performed significantly better than the control group, we must be cautious. In order to apply such a finding would be ill conceived. What we do know, from the findings, there is indeed a better way to cue the driver to his or her speed within a work zone as compared to regular road signage, at least within this simulated environment.
Implications of Results

Let us discuss how these findings could relate to safety, first as discussed in the opening chapter, speed is a major factor in work zone injuries and fatalities. It is clear; the audio signal elicits a quicker response which slows the driver to a safe and manageable speed. In addition, an audio cue does not tax the visual system while a visual cue might distract from the visual demands of driving. As mentioned in a study by Hughes and Cole, 50% to 70% of the visual demand is allocated to the driving task. Furthermore, it goes without saying that the reason for controlling speed through a work zone is to deter and reduce injuries and death of workers as well as drivers and their passengers. In addition, these findings could have design implications and will be discussed.

Limitations

The experimental drive started with all participants beginning at the same initial starting point. They drove approximately 3 to 5 minutes before reaching the first signal (work zone ahead); they drove for approximately one minute and the reached the beginning of the work zone where they received the begin work zone warning message. They spent another 2 to 4 minutes in the work zone. The control group received regular road signage while the audio and visual groups received the appropriate warning messages along with the regular road signage. During the experiment both the audio and visual group warning messages at the work zone ahead sign failed four times out of twenty (i.e., participants did not receive the warning message). All other signals within the experiment worked without failure. There was no observed effect by four participants missing the signal (please see Appendix L). In the construction of the simulations there were no vehicles added to the experimental drive. This approach was taken for a couple of reasons, first,
the simulated vehicles do not behave consistently which would introduce confounds into the
dependent measures. Secondly, the simulator itself only allows a certain number of objects
(cones, people, etc…) to be incorporated into any one simulation. For this particular simulator
the machine will not load the scenario if over 110 objects are exceeded. This also dictated the
length of the work zone, which utilized the maximum number of objects; further, one must
consider the added burden on the visual system if indeed vehicles had been added, giving further
support for the use of the audio modality as a cueing channel for work zone warning messages.
In fact, there were no other moving entities except the owncab as it traveled through the
simulated environment. So, from this perspective, this would probably be the most basic
configuration of work zone. In any other work zone configuration visual demand would increase
due the fact of the movement of workman, bicyclist, or any type of various vehicles. Thus, in
theory, this would strengthen the findings of this study; that is, the audio modality is a much
better channel to cue the driver to his or her speed throughout this critical driving event.
However, in everyday driving there were variables that were not included in this study. For
instance, many people drive with the radio on, do you think for a minute that these folks would
voluntarily turn their radios off at a work zone ahead sign.

**Suggestions for Future Research**

One interesting finding was that the audio group responded much quicker; in fact, within the first
6 seconds of the work zone the audio group was in compliance while it took the visual group 22
seconds. It would be interesting to apply this approach to real drivers in real work zones. There is
always the underlying question, does the simulator represent the real world and do the findings
apply. In addition, driver age must be considered during the implementation of any in-vehicle
system including an In-vehicle Signing and Information System (ISIS). Prior studies suggest older drivers must monitor the road closely in order to avoid loss of vehicular control. Furthermore, younger driver’s performance and their ability to perform secondary driving tasks are superior compared to older drivers (Mollenhaur, Lee, Cho, Hulse, & Dingus, 1994). However, older drivers seem to be aware of this and compensate by taking more time to make critical driving decisions.

A study by Wickens, Braune, and Stokes (1987) investigated age differences pertaining to speed and capacity of information processing. Within this experiment, tasks were developed to assess aging using a dichotic-listening task, a tracking-task for perceptual-motor speed as well as a transcription task. The overall findings illustrate a clear decrement in processing as individuals increase in age (Figure 38).
The suggestions for further research are many! The first is combining the audio with the visual in the redundant presentation of warning messages. Perhaps this would afford the driver the opportunity to select his or her best fit for the presentation of the stimuli, or perhaps aggravate the drivers in some unseen manner. Another approach is to possibly just use an initial tone to alert the driver to the visual presentation of the information. In addition, older drivers were not included in these experiments and while they do compensate for their age by allowing more time to make decisions for safe driving they may react differently to modalities for several reasons (e.g., hearing often declines with age).
Design Recommendations

The primary goal of this project is to provide possible design recommendations for safe delivery of warning messages within work zones by reducing a driver’s speed through a work zone. In the multi-tasking environment of driving it is assumed that the driver will intuitively keep the primary task above all other tasks (Wickens & Gosney, 2003). Thus, all other tasks become secondary in importance. With this in mind and the findings of this research a potential design is discussed below.

We would suggest a redundant signal would be appropriate based on the findings. That is, for the first few seconds a combined audio and visual warning message would be optimum followed by a visual warning message only. This is possible with the advent of Global Positioning Systems (GPS) and in-vehicle navigation systems that track the location of the vehicle and provide important information to the driver about his or her location. The following paragraphs will explore the possibility of using this existing technology and modifying it for the delivery of work zone messages. Of course, further research needs to be conducted to examine if a unique simple short tone to upcoming work zones would be a better delivery of the initial warning message as compared to a text based message that was utilized during this research.

First, let’s take a look at how basic GPS system works. A GPS receiver calculates its position by measuring the distance between itself and three or more GPS satellites. Measuring the time delay between transmission and reception of each GPS radio signal gives the distance to each satellite, since the signal travels at a known speed. The signals also carry information about the satellites'
location. By determining the position of, and distance to, at least three satellites, the receiver can compute its position using trilateration. Receivers typically do not have perfectly accurate clocks and therefore track one or more additional satellites to correct the receiver's clock error. Next, how does the GPS system interface with the navigation system?

An automotive navigation system is a satellite navigation system designed for use in automobiles. According to J.D. Power and associates 1.8 million automobiles with navigation systems were sold in 2006. Global Positioning Systems use position data to locate the user on a road in the units map database. Using the road database, the unit can give directions to other locations. The road database is a vector map of some area of interest. Street names or numbers and house numbers are can be encoded as geographic coordinates so that the user can find some desired destination by street address. Points of interest (waypoints) can also be stored with their geographical coordinates. Point of interest includes fuel stations, public parking, or just your favorite spot. Likewise, contents can be produced by the user base as they travel from one point to another point via Wi-Fi through the internet which can be updated in near real-time. Until recently, vehicle navigation systems have utilized CD or DVD for map information supplied to the driver. However, Inrix, a spin off company of Microsoft now provides real-time and predictive traffic nationwide to web portals, personal navigation systems, automotive and tier one suppliers as well as regional and federal government and many others. Inrix already works with state Department of Transportation organizations to gather relative real-time information for drivers. At this point, the company does supply information about construction; however, there is not a well designed system for work zones. Instead of the traditional signage for the conventional
work zone (out-of-vehicle signage), a engineer could collect waypoints during the engineering phase of a work zone to be uploaded through a web site to the end user.
Statement of Informed Consent

The University of Central Florida and the UCF Department of Psychology support the protection of human subjects in research. We are presenting the following information so that you can decide whether you wish to participate in this study. For this research study, you will be asked to complete questionnaires. You will be asked to answer questions about yourself. In addition you will be asked to drive a route using a driving simulator. We are not interested in any particular person’s individual responses. You are not required to answer or participate in any part of the research, and you do not have to give any reason for not participating in any part of the research. Furthermore, all of the data collected in this study will be kept completely confidential and throughout the study you will be identified by a subject number only. No names will be used. This subject number will not be linked to your name in any way.

Discomforts should be minimal to you as a subject in this study. Simulators and virtual environments can cause different types of sickness: visuomotor dysfunctions (such as eyestrain, blurred vision, difficulty in focusing), mental disorientation (difficulty in concentrating, confusion, apathy), and nausea (including vomiting). Other symptoms may include drowsiness, fatigue, and headache. We have taken precautions to minimize the risk of simulator sickness symptoms during the experiment. However, if you had past experience with simulator sickness we recommend that you withdraw form the experiment. The benefit to your participation in this study is added knowledge about participation in psychological research. You will be compensated for your participation in this research through experimental credit for courses as well as a one time payment of 8 dollars payment. Your participation is strictly voluntary and you may withdraw at any time without negative consequences. Your participation in this research is not expected to last beyond one, one-hour experimental session. If you wish to see the results of this study, you may request a write up of them form the investigators listed below. Additionally, you may contact the investigators with questions about this research.

Primary Investigators:

Tal Oron-Gilad
Department of Psychology
University of Central Florida (407) 823-0923
torongil@mail.ucf.edu

James D. Whitmire II
Modeling & Simulation
University of Central Florida (407) 882-0289
jwhitmir@ist.ucf.edu

If you believe you have been injured during participation in this research project, you may file a claim against the State of Florida by filing a claim with the University of Central Florida’s Insurance Coordinator, Purchasing Department, 4000 Central Florida Boulevard, Suite 360, Orlando, FL 32816, (407) 823-2661. The University of Central Florida is an agency of the State of Florida, and its and the state’s liability for personal injury or property damage is extremely limited under Florida law. Accordingly, the university’s and the state’s ability to compensate you for any personal injury or property damage suffered during this research project is very limited.

Information regarding your rights as a research volunteer may be obtained form:

IRB Coordinator
Institutional Review Board (IRB)
University of Central Florida (UCF)
12443 Research Parkway, Suite 207
Orlando, Florida 32826-3252
Telephone: (407) 823-2901
I have read the procedure described above. I voluntarily agree to participate in the procedure, and I have received a copy of this description.

__________________________________________________________________________

Research Project Title: UTILIZATION OF IN-VEHICLE WARNING SYSTEMS FOR THE ENHANCEMENT OF WORK ZONE SAFETY

__________________________________________________________________________

Signature of Participant

Date ____________________

__________________________________________________________________________

Printed Name of Participant

__________________________________________________________________________

Researcher Name
Please tick one box only unless otherwise indicated (do not write in boxes at right margin).

Section A
1. Please state your age in years: ____________

2. Please state your sex: Male ☐ Female ☐

3. What is your highest educational qualification? ____________

4. Please state your occupation: ____________

5. Please state the year when you obtained your full driving licence: 19___

6. About how often do you drive nowadays?
   Everyday ☐ 2-3 days a week ☐ About once a week ☐ Less often ☐

7. Estimate roughly how many miles you personally have driven in the past year:
   Less than 5000 miles ☐ 5000-10,000 miles ☐ 10,000-15,000 miles ☐
   15,000-20,000 miles ☐ Over 20,000 miles ☐

8. Do you drive to and from your place of work?
   Everyday ☐ Most days ☐ Occasionally ☐ Never ☐

9. Please state whether you drive frequently on:
   (tick one or more boxes as appropriate)
   Motorways ☐ Other main roads ☐ Urban roads ☐ Country roads ☐

10. During the last three years, how many minor road accidents have you been involved in?
    (A minor accident is one in which no-one required medical treatment, AND costs of damage to vehicles and property were less than £500).
    Number of minor accidents ____________ (if none, write 0)

11. During the last three years, how many major road accidents have you been involved in?
    (A major accident is one in which EITHER someone required medical treatment, OR costs of damage to vehicles and property were greater than £500, or both).
    Number of major accidents ____________ (if none, write 0)

12. During the last three years, have you ever been convicted for:
    (a) Speeding ☐ Yes ☐ No ☐
    (b) Careless or dangerous driving ☐ Yes ☐ No ☐
    (c) Driving under influence of alcohol/drugs ☐ Yes ☐ No ☐
Section B

Please answer the following questions on the basis of your usual or typical feelings about driving. Each question asks you to answer according to how strongly you agree with one or other of two alternative answers. Please read each of the two alternatives carefully before answering. To answer, put a cross on the horizontal line at the point which expresses your answer most accurately. Be sure to answer all the questions, even if some of them don’t seem to apply to you very well: guess as best you can if need be.

Example: Are you a confident driver?
The more confident you are, the closer to the ‘very much’ alternative you should mark your cross. If you are quite a confident driver you might mark it like this:

not at all
0 1 2 3 4 5 6 7 8 9 10
very much

1. Does it worry you to drive in bad weather?
very much
2. I am disturbed by thoughts of having an accident or the car breaking down
very rarely
3. Do you lose your temper when another driver does something silly?
not at all
4. Do you think you have enough experience and training to deal with risky situations on the road safely?
not at all
5. I find myself worrying about my mistakes and the things I do badly when driving
very rarely
6. I would like to risk my life as a racing driver
not at all
7. My driving would be worse than usual in an unfamiliar hired car
not at all
8. I sometimes like to frighten myself a little while driving
very much
9. I get a real thrill out of driving fast
very much
10. I make a point of carefully checking every side road I pass for emerging vehicles
very much
11. Driving brings out the worst in people
not at all
12. Do you think it is worthwhile taking risks on the road?
very much
13. At times, I feel like I really dislike other drivers who cause problems for me
very much
14. Advice on driving from a passenger is generally:
useful
15. I like to raise my adrenaline levels while driving
not at all

very much
16. It's important to show other drivers that they can't take advantage of you
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

17. Do you feel confident in your ability to avoid an accident?
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

18. Do you usually make an effort to look for potential hazards when driving?
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

19. Other drivers are generally to blame for any difficulties I have on the road
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

20. I would enjoy driving a sports car on a road with no speed-limit
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

21. Do you find it difficult to control your temper when driving?
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

22. When driving on an unfamiliar road do you become more tense than usual?
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

23. I make a special effort to be alert even on roads I know well
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

24. I enjoy the sensation of accelerating rapidly
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

25. If I make a minor mistake when driving, I feel it's something I should be concerned about
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

26. I always keep an eye on parked cars in case somebody gets out of them, or there are pedestrians behind them
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

27. I feel more anxious than usual when I have a passenger in the car
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

28. I become annoyed if another car follows me very closely for some distance
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

29. I make an effort to see what's happening on the road a long way ahead of me
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

30. I try very hard to look out for hazards even when it's not strictly necessary
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

31. Are you usually patient during the rush hour?
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

32. When you overtake another vehicle do you feel in command of the situation?
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

33. When you overtake another vehicle do you feel tense or nervous?
not at all [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] very much [ ] [ ]

34. Does it annoy you to drive behind a slow moving vehicle?
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]

35. When you're in a hurry, other drivers usually get in your way
very much [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] not at all [ ] [ ]
36. When I come to negotiate a difficult stretch of road, I am on the alert
very much 0 1 2 3 4 5 6 7 8 9 10 not at all □

37. Do you feel more anxious than usual when driving in heavy traffic?
not at all 0 1 2 3 4 5 6 7 8 9 10 very much □

38. I enjoy cornering at high speed
not at all 0 1 2 3 4 5 6 7 8 9 10 very much □

39. Are you annoyed when the traffic lights change to red when you approach them?
very much 0 1 2 3 4 5 6 7 8 9 10 not at all □

40. Does driving usually make you feel aggressive?
very much 0 1 2 3 4 5 6 7 8 9 10 not at all □

41. Think about how you feel when you have to drive for several hours, with few or no breaks from driving. How do your feelings change during the course of the drive?

a) More uncomfortable physically (e.g. headache or muscle pains)

b) More drowsy or sleepy

0 1 2 3 4 5 6 7 8 9 10 No change

No change

Reactions to other traffic increasingly slow

Become increasingly inattentive to road-signs

Your vision becomes less clear

Normal judgement of speed

Increasingly bored and fed-up

No change

Interest in driving does not change

Interest in driving decreases

Increasingly risky and dangerous

Overtaking becomes increasingly risky and dangerous

Office use only a) □ □ □ □ □ □ □ □ □ □ b) □ □ □ □ □ □ □ □ □ □ c) □ □ □ □ □ □ □ □ □ □ d) □ □ □ □ □ □ □ □ □ □ e) □ □ □ □ □ □ □ □ □ □ f) □ □ □ □ □ □ □ □ □ □ g) □ □ □ □ □ □ □ □ □ □ h) □ □ □ □ □ □ □ □ □ □
APPENDIX C: DRIVER COPING QUESTIONNAIRE
These questions are concerned with how you usually deal with driving when it is difficult, stressful or upsetting. Think of those occasions during the last year when driving was particularly stressful. Perhaps you nearly had an accident, or you were stuck in a traffic jam, or you had to drive for a long time in poor visibility and heavy traffic. Use your experiences of driving during the last year to indicate how much you usually engage in the following activities when driving is difficult, stressful or upsetting, by circling one of the numbers from 0 to 5 to the right of each question.

<table>
<thead>
<tr>
<th>Question</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Relieved my feelings by taking risks or driving fast</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Cheered myself up by thinking about things unrelated to the drive</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. Stayed detached or distanced from the situation</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Tried to make other drivers more aware of me by driving close behind them</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. Wished that I was a more confident and forceful driver</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Ignored my feelings about the drive</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. Made sure I avoided reckless or impulsive actions</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. Showed other drivers what I thought of them</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. Drove assertively or aggressively</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. Tried to gain something worthwhile from the drive</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11. Showed other drivers I was in control of the situation</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12. Made an extra effort to drive safely</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13. Felt that I was becoming a more experienced driver</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14. Made an effort to stay calm and relaxed</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15. Swore at other drivers (aloud or silently)</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. Thought about good times I've had</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17. Wished that I found driving more enjoyable</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18. Made sure I kept a safe distance from the car in front</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19. Went on as if nothing had happened</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20. Refused to believe that anything unpleasant had happened</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21. Told myself there wasn't really any problem</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22. Let other drivers know they were at fault</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23. Criticised myself for not driving better</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>24. Thought about the consequences of having an accident</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>25. Flashed the car lights or used the horn in anger</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>26. Felt I was learning how to cope with stress</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>27. Deliberately slowed down when I met a difficult traffic situation or bad weather</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>28. Made a special effort to look out for hazards</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>29. Blamed myself for getting too emotional or upset</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>30. Concentrated hard on what I had to do next</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>31. Worried about what I was going to do next</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>32. Looked on the drive as a useful experience</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>33. Worried about my shortcomings as a driver</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>34. Thought about the benefits I would get from making the journey</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>35. Learnt from my mistakes</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
APPENDIX D: NASA TLX
<table>
<thead>
<tr>
<th>Question</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much mental activity was required (thinking, deciding, calculating, remembering, looking, and searching)? Was the task easy or demanding?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>MENTAL DEMAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much physical activity was required (pushing, pulling, turning, controlling, and activating)? Was the task easy or demanding, slow or brisk, slack or strenuous?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>PHYSICAL DEMAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much time pressure did you feel due to the rate or pace at which the task or parts of the task occurred? Was the pace slow and leisurely or rapid and frantic?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>TEMPORAL DEMAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How hard did you have to work (mentally and/or physically) to accomplish your level of performance?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>EFFORT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>FRUSTRATION</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E: PRE-SIMULATION SICKNESS QUESTIONNAIRES
PRE-EXPOSURE BACKGROUND INFORMATION

1. How long has it been since your last exposure in a simulator? ______ days
   How long has it been since your last flight in an aircraft? ______ days
   How long has it been since your last voyage at sea? ______ days
   How long has it been since your last exposure in a virtual environment? ______ days

2. What other experience have you had recently in a device with unusual motion?

PRE-EXPOSURE PHYSIOLOGICAL STATUS INFORMATION

3. Are you in your usual state of fitness? (Circle one)     YES       NO
   If not, please indicate the reason:

4. Have you been ill in the past week? (Circle one)     YES       NO
   If "Yes", please indicate:
   a) The nature of the illness (flu, cold, etc.):
   b) Severity of the illness: Very Mild_____Very Severe___________
   c) Length of illness: _____________ Hours / Days
   d) Major symptoms:
   e) Are you fully recovered? YES NO

5. How much alcohol have you consumed during the past 24 hours?
   ______ 12 oz. cans/bottles of beer     ______ ounces wine     ______ ounces hard liquor

6. Please indicate all medication you have used in the past 24 hours. If none, check the first line:
   a) NONE
   b) Sedatives or tranquilizers
   c) Aspirin, Tylenol, other analgesics
   d) Anti-histamines
   e) Decongestants
   f) Other (specify):

7. a) How many hours of sleep did you get last night? ______ hours
   b) Was this amount sufficient? (Circle one)     YES       NO

8. Please list any other comments regarding your present physical state which might affect your performance on our test battery.
Baseline (Pre) Exposure Symptom Checklist

Instructions: Please fill this out BEFORE you go into the virtual environment. Circle how much each symptom below is affecting you right now.

<table>
<thead>
<tr>
<th>#</th>
<th>Symptom</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>General discomfort</td>
<td>None</td>
</tr>
<tr>
<td>2.</td>
<td>Fatigue</td>
<td>None</td>
</tr>
<tr>
<td>3.</td>
<td>Boredom</td>
<td>None</td>
</tr>
<tr>
<td>4.</td>
<td>Drowsiness</td>
<td>None</td>
</tr>
<tr>
<td>5.</td>
<td>Headache</td>
<td>None</td>
</tr>
<tr>
<td>6.</td>
<td>Eye strain</td>
<td>None</td>
</tr>
<tr>
<td>7.</td>
<td>Difficulty focusing</td>
<td>None</td>
</tr>
<tr>
<td>8a.</td>
<td>Salivation increased</td>
<td>None</td>
</tr>
<tr>
<td>8b.</td>
<td>Salivation decreased</td>
<td>None</td>
</tr>
<tr>
<td>9.</td>
<td>Sweating</td>
<td>None</td>
</tr>
<tr>
<td>10.</td>
<td>Nausea</td>
<td>None</td>
</tr>
<tr>
<td>11.</td>
<td>Difficulty concentrating</td>
<td>None</td>
</tr>
<tr>
<td>12.</td>
<td>Mental depression</td>
<td>None</td>
</tr>
<tr>
<td>13.</td>
<td>“Fullness of the head”</td>
<td>None</td>
</tr>
<tr>
<td>14.</td>
<td>Blurred Vision</td>
<td>None</td>
</tr>
<tr>
<td>15a.</td>
<td>Dizziness with eyes open</td>
<td>None</td>
</tr>
<tr>
<td>15b.</td>
<td>Dizziness with eyes closed</td>
<td>None</td>
</tr>
<tr>
<td>16.</td>
<td>*Vertigo</td>
<td>None</td>
</tr>
<tr>
<td>17.</td>
<td>**Visual flashbacks</td>
<td>None</td>
</tr>
<tr>
<td>18.</td>
<td>Faintness</td>
<td>None</td>
</tr>
<tr>
<td>19.</td>
<td>Aware of breathing</td>
<td>None</td>
</tr>
<tr>
<td>20.</td>
<td>***Stomach awareness</td>
<td>None</td>
</tr>
<tr>
<td>21.</td>
<td>Loss of appetite</td>
<td>None</td>
</tr>
<tr>
<td>22.</td>
<td>Increased appetite</td>
<td>None</td>
</tr>
<tr>
<td>23.</td>
<td>Desire to move bowels</td>
<td>None</td>
</tr>
<tr>
<td>24.</td>
<td>Confusion</td>
<td>None</td>
</tr>
<tr>
<td>25.</td>
<td>Burping</td>
<td>None</td>
</tr>
<tr>
<td>26.</td>
<td>Vomiting</td>
<td>None</td>
</tr>
<tr>
<td>27.</td>
<td>Other</td>
<td>None</td>
</tr>
</tbody>
</table>

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Visual illusion of movement or false sensations of movement, when not in the simulator, car, or aircraft.
*** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

STOP HERE! The test director will tell you when to continue.
APPENDIX F: POST-SIMULATION SICKNESS QUESTIONNAIRES
POST 00 Minutes Exposure Symptom Checklist

Instructions: Circle how much each symptom below is affecting you right now.

<table>
<thead>
<tr>
<th>#</th>
<th>Symptom</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General discomfort</td>
<td>None Slight</td>
</tr>
<tr>
<td>2</td>
<td>Fatigue</td>
<td>None Slight</td>
</tr>
<tr>
<td>3</td>
<td>Boredom</td>
<td>None Slight</td>
</tr>
<tr>
<td>4</td>
<td>Drowsiness</td>
<td>None Slight</td>
</tr>
<tr>
<td>5</td>
<td>Headache</td>
<td>None Slight</td>
</tr>
<tr>
<td>6</td>
<td>Eye strain</td>
<td>None Slight</td>
</tr>
<tr>
<td>7</td>
<td>Difficulty focusing</td>
<td>None Slight</td>
</tr>
<tr>
<td>8a</td>
<td>Salivation increased</td>
<td>None Slight</td>
</tr>
<tr>
<td>8b</td>
<td>Salivation decreased</td>
<td>None Slight</td>
</tr>
<tr>
<td>9</td>
<td>Sweating</td>
<td>None Slight</td>
</tr>
<tr>
<td>10</td>
<td>Nausea</td>
<td>None Slight</td>
</tr>
<tr>
<td>11</td>
<td>Difficulty concentrating</td>
<td>None Slight</td>
</tr>
<tr>
<td>12</td>
<td>Mental depression</td>
<td>None Slight</td>
</tr>
<tr>
<td>13</td>
<td>“Fullness of the head”</td>
<td>None Slight</td>
</tr>
<tr>
<td>14</td>
<td>Blurred Vision</td>
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</tr>
<tr>
<td>15a</td>
<td>Dizziness with eyes open</td>
<td>None Slight</td>
</tr>
<tr>
<td>15b</td>
<td>Dizziness with eyes closed</td>
<td>None Slight</td>
</tr>
<tr>
<td>16</td>
<td>*Vertigo</td>
<td>None Slight</td>
</tr>
<tr>
<td>17</td>
<td>**Visual flashbacks</td>
<td>None Slight</td>
</tr>
<tr>
<td>18</td>
<td>Faintness</td>
<td>None Slight</td>
</tr>
<tr>
<td>19</td>
<td>Aware of breathing</td>
<td>None Slight</td>
</tr>
<tr>
<td>20</td>
<td>***Stomach awareness</td>
<td>None Slight</td>
</tr>
<tr>
<td>21</td>
<td>Loss of appetite</td>
<td>None Slight</td>
</tr>
<tr>
<td>22</td>
<td>Increased appetite</td>
<td>None Slight</td>
</tr>
<tr>
<td>23</td>
<td>Desire to move bowels</td>
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</tr>
<tr>
<td>24</td>
<td>Confusion</td>
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</tr>
<tr>
<td>25</td>
<td>Burping</td>
<td>None Slight</td>
</tr>
<tr>
<td>26</td>
<td>Vomiting</td>
<td>None Slight</td>
</tr>
<tr>
<td>27</td>
<td>Other</td>
<td>None Slight</td>
</tr>
</tbody>
</table>

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Visual illusion of movement or false sensations of movement, when not in the simulator, car or aircraft.
*** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

POST-EXPOSURE INFORMATION
1. While in the virtual environment, did you get the feeling of motion (i.e., did you experience a compelling sensation of self motion as though you were actually moving)? * (Circle one) 

   YES  NO  SOMEWHAT

2. On a scale of 1 (POOR) to 10 (EXCELLENT) rate your performance in the virtual environment:

3. a. Did any unusual events occur during your exposure? * (Circle one)  YES  NO 
   b. If YES, please describe
APPENDIX G: INTRODUCING DRIVERS TO THE SIMULATOR
The first thing we will do is get you settled into the vehicle. As you will be driving approximately 10 to 15 minutes we will take the time to make sure you are comfortable.

**SEAT**
Encourage drivers to adjust seat in any way they wish.

To adjust seat fore/aft position lift up the lever on the right hand side of the seat, adjust the seat, then put the lever down to lock seat into its new position.

To adjust seat’s reclining angle lift up the lever on the left hand side of and adjust position to new position.

To adjust the head restraint, simply move restraint on back of seat up and down to desired height.

Ask driver to put on seatbelt.

**INSTRUMENT PANEL**
Take a minute to familiarize yourself with the instrument panel. To the far left is the fuel gauge, and to the right of that is the speedometer.

**PREPARING TO DRIVE**
Tell subjects to keep their hands at the 9:00 and 3:00 positions on the wheel throughout the drive.

**GEAR SHIFT**
Take a minute to familiarize yourself with the gear shift. The gear shift is currently in park; to change the gears pull the gear shift lever towards you and select the appropriate gear. For our exercise today we will be using the park and drive positions only.

**IGNITION**
When we are ready to start the car, place the key into the ignition switch located on the right of the wheel and turn the key away from you.

**PRACTICE: ORIENTATION RIDE**
Before we begin we will let you get acquainted with the automobile simulator by going for a short drive. In this orientation ride you will be on the side of a highway, when it is safe to pull on to the highway please do so and proceed to the Liberty Exit. Take this exit to the right and come to a complete stop at the top of the hill at the stop sign. Place the vehicle in park and notify the experimenter that you are finished with the demonstration ride.

STOP HERE UNTIL DEMO RIDE IS FINISHED!
Instructions for the experiment

During the next 10 to 15 minutes you will drive on the GE driving simulator. This simulation will include a work zone. Before reaching the work zone you will drive for approximately 3 to 5 minutes. Please proceed safely through the work zone. After leaving the work zone pull over to the right and park the vehicle. In addition, there will be two intersections with stop signs, you will be making no turns through this drive and there is no traffic to be concerned with. So please, drive straight throughout the experiment and obey all posted speed limits. You will receive one of three conditions; 1) typical road signs, 2) audio warning message, or a 3) visual warning message.

Please pay attention to all speed limits and keep your vehicle on the pavement.

Thank you for your participation!
APPENDIX I: QUESTIONNAIRE
**Questionnaire**

Where you able to see the visual message clearly?
Yes____ No____ Does Not Apply____

Where you able to understand the visual message?
Yes____ No____ Does Not Apply____

Where you able to hear the audio message clearly?
Yes____ No____ Does Not Apply____

Where you able to understand the audio message clearly?
Yes____ No____ Does Not Apply____

As far as you know, is your hearing normal?
Yes____ No____

Do you suffer from hearing loss?
Yes____ No____

Do you use any type of corrective hearing device?
Yes____ No____
APPENDIX J: IRB
August 22, 2005

Tal Oron-Gilad, Ph.D.
Department of Psychology
PH 302
University of Central Florida
Orlando, FL 32816-1390

Dear Dr. Oron-Gilad:

With reference to your protocol #05-2800 entitled, “Utilization of In-Vehicle Warning Systems for the Enhancement of Work Zone Safety” I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. This study was approved on 8/21/05 and the expiration date will be 8/20/06. Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman or full IRB at least one month prior to the expiration date. This is the responsibility of the investigator. Please notify the IRB office when you have completed this research study.

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

Barbara Ward, CIM
IRB Coordinator

Copies: IRB File
     James D. Whitmire II

BW: jim
APPENDIX K: SIMULATION SICKNESS RESULTS
General Linear Model

Within-Subjects Factors
Measure: MEASURE_1

<table>
<thead>
<tr>
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<th>Dependent Variable</th>
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<td>1</td>
<td>PreSim</td>
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<td>2</td>
<td>PostSim</td>
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Between-Subjects Factors

<table>
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<tr>
<th>Group</th>
<th>Value Label</th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Control</td>
<td>20</td>
</tr>
<tr>
<td>2.00</td>
<td>Audio</td>
<td>20</td>
</tr>
<tr>
<td>3.00</td>
<td>Visual</td>
<td>20</td>
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</table>

Descriptive Statistics

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<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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<tr>
<td>PreSim</td>
<td>Control</td>
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<td>11.80199</td>
</tr>
<tr>
<td></td>
<td>Audio</td>
<td>4.3010</td>
<td>6.21987</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>7.1060</td>
<td>10.28903</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6.5450</td>
<td>9.70460</td>
</tr>
<tr>
<td>PostSim</td>
<td>Control</td>
<td>16.0820</td>
<td>18.04281</td>
</tr>
<tr>
<td></td>
<td>Audio</td>
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<td>11.39722</td>
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<tr>
<td></td>
<td>Visual</td>
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<tr>
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Multivariate Tests

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<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pillai’s Trace</td>
<td>.167</td>
<td>11.414a</td>
<td>1.000</td>
<td>57.000</td>
</tr>
<tr>
<td>Wilks’ Lambda</td>
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<td>11.414a</td>
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<td>57.000</td>
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<tr>
<td>Roy’s Largest Root</td>
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<td>11.414a</td>
<td>1.000</td>
<td>57.000</td>
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<tr>
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<tr>
<td>Roy’s Largest Root</td>
<td>.005</td>
<td>.156a</td>
<td>2.000</td>
<td>57.000</td>
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</table>
Multivariate Tests

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai's Trace</th>
<th>Wilks' Lambda</th>
<th>Hotelling's Trace</th>
<th>Roy's Largest Root</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td></td>
<td>.167</td>
</tr>
<tr>
<td>factor1 * Group</td>
<td>.856</td>
<td>.856</td>
<td>.856</td>
<td>.856</td>
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</table>

Mauchly's Test of Sphericity

Measure: MEASURE_1

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<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Mauchly's W</th>
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<th>Sig.</th>
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<td>factor1</td>
<td>1.000</td>
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</table>

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

Mauchly's Test of Sphericity

Measure: MEASURE_1

<table>
<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Epsilonab</th>
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<tbody>
<tr>
<td></td>
<td>Greenhouse</td>
</tr>
<tr>
<td>factor1</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept+Group
   Within Subjects Design: factor1
### Tests of Within-Subjects Effects

**Measure: MEASURE_1**

<table>
<thead>
<tr>
<th>Source</th>
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<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>factor1</td>
<td>Sphericity Assumed</td>
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<td>1</td>
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</tr>
<tr>
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<td>Greenhouse-Geisser</td>
<td>2046.993</td>
<td>1.00</td>
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<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>2046.993</td>
<td>1.00</td>
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</tr>
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<td></td>
<td>Lower-bound</td>
<td>2046.993</td>
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<td>2046.993</td>
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<td>factor1 * Group</td>
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<td>Lower-bound</td>
<td>55.908</td>
<td>2.00</td>
<td>27.954</td>
</tr>
<tr>
<td>Error(factor1)</td>
<td>Sphericity Assumed</td>
<td>10222.579</td>
<td>57</td>
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</tr>
<tr>
<td></td>
<td>Greenhouse-Geisser</td>
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<td>57.00</td>
<td>179.343</td>
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<td></td>
<td>Huynh-Feldt</td>
<td>10222.579</td>
<td>57.00</td>
<td>179.343</td>
</tr>
<tr>
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<td>Lower-bound</td>
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<td>57.00</td>
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## Tests of Within-Subjects Effects

Measure: MEASURE_1

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<tr>
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<td>Huynh-Feldt</td>
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<tr>
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## Tests of Within-Subjects Contrasts

Measure: MEASURE_1

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<td>2</td>
<td>27.954</td>
<td>.156</td>
<td>.856</td>
<td>.005</td>
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<tr>
<td>Error(factor1)</td>
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<td>57</td>
<td>179.343</td>
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</table>

## Tests of Between-Subjects Effects

Transformed Variable: Average

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<tr>
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<th>Mean Square</th>
<th>F</th>
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<td>287.645</td>
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APPENDIX L: EQUIPMENT LIMITATIONS
During the experiment both the audio and visual group work zone ahead signal failed four times out of twenty. All other signals within the experiment worked without failure. This opens the question, did the four participants in the audio as well as the four participants in the visual group respond differently in the work zone causing an erroneous finding? The following figures attempt to answer this question.

The following figure illustrates five driving attributes collected directly from the driver’s behavior up to the work zone ahead sign in the audio group. The data clearly illustrates that for the four participants that received no signal at the work zone ahead sign that there was little change in their driving behaviors.

The following figure shows the difference between the four participants in the audio group that did not receive the audio warning message and the sixteen participants that did receive the audio warning message. Probably, the most important measurement is speed which shows that the four participants exceeded there counterpart by 1.95 miles per hour. This trend is almost completely opposite for the visual group.
The next figure examines the differences between the four participants that did not receive the begin work zone audio message and the 16 participants that did receive the begin work zone audio message. There were slight differences that, however, not significant.

The next figure shows the actual speed at the work zone ahead sign; the mean for the 16 participants was 60 mph while the mean for the 4 participants was 64 mph.
The following figure illustrates five acceleration collected directly from the driver’s behavior up to the work zone ahead sign in the visual group. The data clearly illustrates that for the four participants that received no signal at the work zone ahead sign that there was little change in their driving behaviors.

The following figure represents the data after the work zone ahead sign up to the begin work zone sign. As the reader can ascertain, the four participants for the visual group were slower by approximately 2 miles per hour than the sixteen participants that received the cue. If one considers that the audio group was opposite it is possible that there was no change whatsoever. This will be further discussed in the discussion section of this report.
The following figure represents the data from the start of the driving scenario up to the begin work zone sign. As the reader can ascertain, the four participants for the visual group were slower by approximately 1 mile per hour than the sixteen participants that received the cue.

The next represents the difference within the visual group pertaining to the speed at the work zone ahead sign warning message. Please notice that for the visual group that the 4 participants are 3mph slower which is almost the opposite that was found for the audio group.
The following figure illustrates the speeds at the work zone ahead sign; interestingly, if the audio and visual groups averaged equals 59.2 mph leaving less than a 1 mile an hour difference between the control group and the average of the two experimental groups.

The previous descriptivism certainly make a strong case that the four participants in the audio group and the four participants in the visual group that did not receive the work zone ahead warning message had little to no effect on the driver’s behavior within the work zone.
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