Human Factors Study on the Use and Effectiveness of Innovative Safety Messages on Dynamic Message Signs

Final Report

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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16. Abstract

Dynamic message signs (DMS) are traffic control devices on highways that provide travelers with valuable traffic information. Recently, some state transportation agencies developed nontraditional and sometimes humorous messages for DMS with the intent to modify driver behavior by capturing attention and provoking an emotional response to increase effectiveness. However, there is no scientific evidence to support the effect that creative messages have on changing behavior. The purpose of this research is to study how different age group drivers; young (18-34), middle-age (35-64), and older (65+) comprehend and respond to the safety messages in a controlled setting using a driving simulator and an eye-tracking device. (92) Participants ages 18+ (46 males and 46 females) were recruited for the experiment. The parameters consisted of three two-level factors and one four-level factor resulting in 16 scenarios per participant. The statistical analysis revealed that drivers tend to notice the traditional signs faster but look at creative signs longer. Further analysis demonstrated that the latter effect was due to specific message categories having more words per sign. The driver's time-to-collision was increased more in the presence of creative versus traditional signs which indicated safer conditions. Overall, creative signs, led to a greater increase in time-to-collision with reduced lane position shifts compared to traditional signs with female drivers showing less changes in lane position following the road signs compared to male drivers. Speeds were consistently lower in the creative message scenarios and across message categories past the road signs. Another interesting finding revealed that when the number of words on the message increased, speeds decreased especially longer messages with 6-8 words which can be attributed to the fact that effective communication messages to the driver with a reasonable number of words increase the drivers' cognitive abilities and influence driver behavior in a positive manner. The results revealed that creative messages had a positive influence on driver behavior compared to the traditional messages in terms of reduced speeds, reduced acceleration, and increased time to collision, with less lane position changes. Both the objective and subjective datasets were in agreement related to improved driving behavior. The results of this research will be used to update FDOT's safety message approval process and criteria (Topic Number 000-750-015).

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EXECUTIVE SUMMARY

Dynamic message signs (DMS) are traffic control devices on the highways that provide travelers with roadway traffic conditions and other valuable information. They have become the accepted and preferred method on the highways for delivering real-time traffic-related information. FDOT uses Policy No. 000-750-015, "Displaying Messages on Dynamic Message Signs Permanently Mounted on the State Highway System" which provides guidance to the FDOT in accordance with Chapter 2L, Changeable Message Signs, in the *Manual on Uniform Traffic Control Devices* (MUTCD). This policy is used by State Traffic Engineering and Operations Office to establish a process for approving safety messages for use on the DMS.

Recently, some state transportation agencies across the country developed nontraditional, more humorous messages on these dynamic message signs. Their intent is to modify driver behavior by provoking an emotional response using themes like popular culture, sports, or rhymes to increase effectiveness. However, there is little or no scientific evidence to support the effect that creative messages have on changing behavior. The purpose of this research was to study how different age group drivers; young (18-34), middle-age (35-64), and older (65+) comprehend and respond to the safety messages in a controlled setting using a driving simulator and eye-tracking system. The results of this research will be used by FDOT, as well as other state and local agencies, to develop guidelines and criteria on the appropriate use of creative safety messages. The nontraditional DMS effect on driver behavior has received little attention in the literature, and the main objective of this project was to fill this gap and evaluate their effectiveness on promoting safety and changing driver behavior. Although creative messages on DMS are increasingly utilized throughout the United States, with high relevance to public safety, the effectiveness of standard versus creative messages has yet to be empirically validated. Based on the literature review, this work is the first to test the effect of traditional versus creative messages in a variety of conditions on aspects of driving behavior and visual attention.

All procedures outlined in this research were approved by the university's Institutional Review Board (IRB). A specific protocol was designed, and a consent form was given to each participant to explain the process of the research and obtain their approval. Ninety-two (92) participants ages 18 and up (46 males and 46 females) were recruited for the experiment. The 92 participants were recruited to participate in the study through a variety of mechanisms, which included student recruitment (UCF SONA), Learning Longevity Research Network (LLRN), Learning Institute for Elders (LIFE), social media outreach, fliers, and personal connections. Participants were required to have a driver's license, with normal vision, and be over the age of 18. The study utilized a driving simulator in conjunction with an eye-tracking system to assess driver behavior towards different types of messages.

Participants were asked to fill out surveys to document their experience with motion sickness and simulations. Participants also filled out simulator sickness questionnaires throughout the study to track their response to driving in a simulator over an extended period. After filling out the initial questionnaires, drivers underwent a series of driving scenarios with the varying driving conditions. The aim of putting participants in the simulator was to objectively test their driving performance and perception factors, such as deceleration, braking behavior, lane deviation, and speed of perception (time to notice) in reaction to the displayed safety messages. For determining speed of perception, an eye-tracker was used in combination with the simulator to be able to

determine where participants were looking on the screen. After the simulator runs, drivers were asked to fill out an exit survey for determining the participants' own subjective responses to the different messages they encountered, whether they noticed the messages, and whether it affected their behavior.

The STISIM driving simulator at UCF was utilized for the experiment and data collection which provided a high-fidelity driving testing environment. The exported data consisted of the inputs of the gas pedal, brake pedal, and steering wheel recorded during the experiment. Eye movements were recorded at a rate of 60 Hz using the FOVIO eye tracker in conjunction with Eyeworks software. This low-profile enclosed system mounts inconspicuously on the dashboard and offers fast noninvasive calibration for research subjects and improved eye tracking especially for nighttime conditions. Eye movement data were acquired in real-time with multiple metrics, including time to notice (TTN) the message, fixation duration, and dwell time. Analysis of the frequency of fixations within a pre-specified Area of Interest (AOI) was used to determine how participants allocated their attention to the safety messages.

The design of experiment parameters consisted of three two-level factors and one four-level factor. The standard number of full factorial design needed to cover all cases would amount to 32 (2^3X4^1) runs for each applicant. The factors (levels) were Time of Day (Daytime, Nighttime), Traffic Density (Low, High), Message Type (Traditional, Creative) and Message Category (Work Zone, Speeding, Visibility, and Maneuvering). However, a custom design was used to minimize the number of runs for each participant using D-Optimality Criteria, which resulted in 16 scenarios. In order to measure the behavioral response for each message, a specific scenario was created after each message representing road conditions related to the DMS. For example, a construction zone scenario was added after the work-zone-related messages. The total length of each scenario was two miles.

The total length of the roadway was set to 2 miles with no curvature and three 12-foot lanes per direction. The roadway was divided into six (6) blocks, 0.25 miles each, the speed limit signs, DMS, and the added scenario locations to facilitate the data extraction process. The data were extracted from the driving simulator and then aggregated over two main blocks: Blocks 1-2 and 3-6. Blocks 1-2 represented the aggregated data for the distance driven by the participants up until the DMS, while Blocks 3-6 represented the aggregated data for the distance driven after passing the DMS until the end of the scenario. It should be noted that the eye-tracking data were available from Blocks 1-2 only, while driving data were collected for both blocks. Three main datasets were examined and analyzed. They included driving data, eye-tracking data, and exit survey data. Additional dataset related to motion sickness data, demographic data, and workload were also examined as part of the behavioral data.

The statistical analysis revealed that drivers tended to notice the traditional signs faster but looked at creative signs longer. Further analysis demonstrated that the latter effect was due, in part, to specific message categories having more words per sign. Therefore, the analysis demonstrated that specific message categories had a significant effect on driver's visual attention. On the other hand, drivers' visual attention toward road signs differed based on background characteristics, such as age and gender, with young women looking at creative signs longer compared to middle-aged men looking at traditional signs. Also, older participants took slightly longer to notice the road signs compared to younger participants. Thus, varying sign types may cater to different audiences. A significant two-way interaction between message type and traffic density revealed that drivers noticed traditional signs in low-density traffic faster and looked at them for shorter durations, as compared to creative signs in high-density traffic. The two-way interaction between time-of-day and traffic density was also significant, with drivers noticing signs faster and looking for shorter durations during the night and low-density traffic.

The driver's time to collision increased more in the presence of creative versus traditional signs which indicated safer conditions along with speed reductions. Overall, creative signs, led to a greater increase in time to collision with decreased lane position shifts compared to traditional signs. The relative effectiveness of creative versus traditional signs depended, in part, on the sign category. The main effect of age was statistically significant, with middle-age and older drivers having a greater time to collision than younger drivers. A main effect of gender indicated that female drivers had less changes in lane position following the road signs, compared to male drivers. In addition, the significant interaction between sign type and age showed that older participants had reduced time to collision in the presence of traditional signs, as compared to young people viewing creative signs. A significant main effect of time of day indicated that drivers had reduced time to collision and less changes in lane position during nighttime driving. In addition, the main effect of traffic density demonstrated that low-density traffic conditions resulted in less changes in lane position. Moreover, the significant interaction between sign type, time of day and traffic density revealed that drivers had reduced time-to-collision and greater lane changes following traditional sign viewing in low-density nighttime driving, compared to creative sign viewing in high-density daytime driving.

The results revealed that in Blocks 1-2, there was no significant difference in speeds between the message types or categories. However, the age, gender, and traffic density had significant effect on speeds. On the other hand, when looking at Blocks 3-6, it was found that speeds were consistently lower in the creative message scenarios and across message categories compared to Blocks 1-2. Another interesting finding revealed that when the number of words on the message increased, speeds decreased especially longer messages with 6-8 words. This can be attributed to the fact that effective communication messages with a reasonable number of words increase the drivers' cognitive abilities and influence driver behavior in a positive manner.

The exit survey response data from the 92 participants revealed that the messages were noticed by almost all the participants (90 out of 92). Almost half of them were able to recall the messages. Eighty-seven percent reported that the messages were able to change their behavior, and 87% thought the scenarios were logical and represented real life situations. In addition, about 25% provided suggestions on how these messages changed their behavior, such as paying more attention, reducing speed, fog messages, being more mindful of the conditions as well as the space between the other vehicles, acted as a reminder, and becoming more attentive to what's coming ahead. The results revealed that creative messages had a positive influence on driver behavior compared to the traditional messages in terms of reduced speeds, reduced acceleration, and increased time to collision, with less lane position changes. Both the objective and subjective datasets were in agreement related to improved driving behavior, with participants' survey results matching the analysis of the objective performance factors. The results of this research will be used to update FDOT's safety message approval process and criteria (Topic Number 000-750-015).

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I. INTRODUCTION

1.1 Background

Dynamic message signs (DMSs) or changeable message signs (CMS) are traffic control devices on the highways that provide travelers with roadway traffic conditions and other valuable information. They have become the accepted and preferred method on the highways for delivering real-time traffic-related information or alerts 24 hours per day, seven days per week. DMS can display one or more alternative messages and are a critical part of the Florida Department of Transportation (FDOT) Intelligent Transportation Systems (ITS). DMS provide traveler information to warn drivers of traffic congestion, crashes, construction work zones, travel times, amber or silver, or blue alerts, lane blocking incidents, travel advisories, and safety messages. FDOT uses Policy No. 000-750-015, “Displaying Messages on Dynamic Message Signs Permanently Mounted on the State Highway System”, which provides guidance to the FDOT in accordance with Chapter 2L, Changeable Message Signs, in the *Manual on Uniform Traffic Control Devices* (MUTCD). This policy is used by State Traffic Engineering and Operations Office to establish a process for approving safety messages for use on the DMS.

Recently, some state transportation agencies across the country developed nontraditional, more humorous messages on these dynamic message signs. Their intent is to modify driver behavior by provoking an emotional response using themes like popular culture, sports, or rhymes to increase effectiveness. However, there is little or no scientific evidence to support the effect that creative messages have on changing behavior. Furthermore, while thinking outside the box to create and post safety messages to help remind and educate drivers on staying safe and preventing crashes, it is still unknown whether the meaning behind these creative messages is understood by the drivers or can affect their driving behavior. Another key issue is that they are not incorporated in FDOT’s policy nor do they meet the current criteria.

For instance, Arizona DOT displays "Only Sparklers Should Be Lit, Drive Sober" during Independence Day to eliminate driving under the influence (DUI) as shown in **Figure 1-1.** Conversely, one of Tennessee’s popular messages is “Texting and Driving, Oh Cell No.” Iowa and Missouri DOTs are displaying messages such as “Exit to Text It” or “Get Your Head Out of

Your Apps" to raise safety awareness. FDOT displays "Give Your Phone Independence, Put It Down." **Figure 1-2** shows an example of an FDOT safety campaign message on Halloween that says, "Trick or Treat, Buckle your Seat."

Driving is a complex task that requires sensory, perceptual, cognitive, and psychomotor skills (Mouloua et al., 2004; Smither et al., 2004; Walker et al., 2001). Hence, a driver must be able to detect targets (see lanes, colors, signs, displays, warning systems,), perceive (make sense of these static or moving targets), and act upon (decide and respond) in a timely manner to be optimal in his/her driving performance. Therefore, any ineffective use of signs in traffic or roadway design can lead to an increase in driving errors, response time, driver fatigue, loss of situational awareness, and increased workload level. Consequently, this may also lead to an erosion of the safety margin.

The purpose of this research is to study how different age group drivers; younger (18-34), middle (35- 64), and older (65+) comprehend and respond to the safety messages in a controlled setting using a driving simulator and eye tracking system. In general, innovative DMS are focused specifically on distracted, aggressive driving and DUI. Therefore, the results of this research can be used by FDOT, as well as other state and local agencies to develop guidelines and criteria on the appropriate use of creative safety messages. Non-traditional DMS effect on driver behavior have received little attention in the research, and the main objective of this project is to fill this gap and evaluate their effectiveness on promoting safety and changing driver behavior.

Figure 1-1: Arizona DOT Independence Day Message

Figure 1-2: FDOT Halloween Message

1.2 Project Objectives

The main objectives of the proposed project can be summarized as follows:

1. Design a driving simulator experiment to test driver's behavior in response to different safety messages and invite participants across all age groups to validate results.
2. Identify several human factors to be studied and evaluate the effectiveness of innovative safety messages.
3. Develop a statistical model that will accurately analyze the impacts of the safety messages on driver behavior.
4. Determine criteria to be incorporated into FDOT's safety message approval process (Topic Number 000-750-015).

1.3 Summary of Project Tasks

Task 1: Literature Review

Task 2: Research Plan and Design of Experiment

Task 3: Human Factors Experiment and Data Analysis

Task 4: Develop Evaluation Model

Task 5: Draft Report

Task 6: Final Report

II. LITERATURE REVIEW

Several studies have examined the various human factors issues related to driving (e.g., aging and driving, driver distraction and inattention, aggressive driving, in-vehicle devices and display design, driver fatigue). While these issues continue to be a major concern for traffic safety and public health, efforts to mitigate their impact on drivers' daily travel and commuting activities have not been extensively researched. In this task, we have conducted an extensive literature search using key human factors, engineering models and experimental methods. Experimental methods are ways that researchers utilize to measure data with regards to a certain subject. In the context of experimental methods, the subject is DMS. The effects that DMS have on drivers can be measured through driving simulators, laboratory experiments that track cognitive performance, in-field observations, and human factors such as eye tracking devices. Based on the results, we synthesized these research articles using a taxonomic approach to better classify the models and understand the parameters' interrelationships. The results of the literature review are presented in the following sections.

2.1 Simulation Studies and Eye Tracking Devices

Driving simulators are a common way for researchers to obtain data safely and efficiently without compromising the safety of the driver (Yan, 2005; Underwood et al., 2011; Tu et al., 2015; Yan et al., 2016; Chang et al., 2009; De Winter et al., 2009). Driving simulators also include multiple systems that simulate the real world, including visual systems, acoustic sounds, and vibration. Therefore, the driving simulator can be used to collect data for a wide variety of issues spanning across multiple disciplines (Abdel-Aty et al., 2006; Godley et al., 2002; Abou-Senna et al., 2019). In addition, the driving simulator can collect data instantly compared to the real world, which is very tedious and can take months to years for an incident or event to happen, such as a crash.

For example, (Jeihani & Ardeshiri, 2013) conducted a driving simulator study to evaluate the driving speed of drivers in the presence of DMS. Their goal was to investigate if the driver's speed would change and found that DMS did not influence their speed. This study also evaluated the effectiveness of DMS on speed since a message that is not safe would cause a driver to reduce their speed to read the message. Furthermore, the speed that the driver is traveling at has a significant impact on how long a message should be displayed and the number of rows a message should have. For instance, at speeds greater than 55 miles per hour, DMS shall have no more than two (2) rows of text for every 1,000 feet of distance (Colorado Department of Transportation, 2005).

As the driving simulator has many advantages regarding the DMS, there are also some disadvantages of simulators, which primarily include simulator sickness and low-fidelity simulators that do not imitate real-world conditions. Low-fidelity simulators can affect the research and skew the data output, causing the data to be invalid (De Winter et al., 2012). Therefore, a high-quality simulator shall be used to mitigate this problem. Simulator sickness is another problem that can cause participants not to finish a study and therefore skews the data (Kennedy et al., 1992; Frank et al., 1988; Brooks et al., 2010). The simulator sickness can be reduced by allowing participants to take breaks and be informed that this issue could occur.

In addition, an eye-tracking device is another tool used to track human behavior in the field of transportation. Eye-tracking devices can be broken down into three (3) types, and the first eye-tracker dates to the 1970s (Soliday, 1971). These three (3) types include helmet devices, special equipment, and contactless devices. The device used in this study is contactless, known as the Fovio device as shown in **Figure 2-1**.

Figure 2-1: Fovio Eye-Tracking Device

Devices such as helmets and special equipment eye-trackers are used for other purposes in the medical field such as the magnetic resonance imaging (MRI), which takes scans of the brain and other nervous system tissues; electroencephalography (EEG), which measures brain signals; and electromyography (EMG), which measures heart signals. This type of application uses the helmet device most often. Special devices refer to neurophysiology devices, which track eye movement in a tunnel or in other similar conditions, such as Positron Emission Tomography (PET), computed tomography, magnetic resonance imaging (MRI). These types of Eye-tracking devices are not suitable for transportation engineers, as it does not measure where the eyes are glancing at a screen during an instance of time. The contactless devices use two (2) high definition (HD) cameras that track the person's eye and a camera showing a screen with a crosshair where the person is looking. For example, (Edquist et al., 2011) used a driving simulator and an eye-tracking device to track where a participant was looking during the driving task with and without billboards and found that billboards increased the amount of driver distraction during lane changes. Similarly, (Abou-Senna et al., 2019) conducted a human factors study on the use of colors for express lane delineators using a driving simulator and eye tracking device. Their findings showed that white delineators had the shortest time to first notice (TTFN), which was obtained from the eye tracking device. (Abou-Senna et al., 2021) also conducted a follow up study using a driving simulator and eye tracking device with respect to the colors of express lane delineators on different age groups and found that white was the most optimal color for the delineators. (McAvoy, 2011) conducted a study using a driving simulator and eye-tracking regarding work zone speed reductions using dynamic speed signs and static signs devices. The study found that the driver's eye had more information to process with the dynamic signs over the static signs and that the drivers were able to reduce their speed more with the presentation of the static signs.

2.2 In-Vehicle Field Observations

Field observations are defined as data measurements in the real-world setting rather than a driving simulator or virtual reality setting. Since most DMS studies are done in a simulator, there is minimal evidence on field data with respect to DMS. For example, a study was done in Montana on Interstate 90 through the Bozeman Pass Region of Montana, where there is a high prevalence of animal-vehicular collisions. DMS were implemented on this stretch of roadway to see if drivers would change their behavior to prevent animal-vehicular collisions and discovered that crash data obtained from crash reports and speed data in the field were reduced by the DMS message (Hardy et al., 2006).

2.3 Human Factors

Human Factors is the scientific discipline concerned with the understanding of interactions among humans and machine systems based on their capabilities and limitations in other elements of a system (Meister, 1989). The human factors apply theory, principles, data, and other methods to design and optimize the overall human-system performance and safety (Proctor & Van Zandt, 2008). Specifically, human factors in transportation uses principles to understand the actions and capabilities of drivers (and other road users) to optimize the design of the road and enhance safety. There have been several elements within the field of transportation engineering that have benefited from human factors research, including sight distance requirements, work zone layouts, sign design, placement, and spacing criteria, dimensions for pavement markings, color specifications, sign letter fonts and icons, and signal timing (Campbell, 2012). The motor vehicle crash data highlight the importance of human factors to transportation. In 2019, there were more than 6.75 million police-reported (and many more unreported) crashes in the United States, with attendant loss of life, property, and productivity (NHTSA, 2020). (Treat et al., 1977) concluded that human error was the sole cause in 57% of all accidents and was a contributing factor in over 90%.

In addition, driver fatigue is a serious safety problem that costs many people their lives, and different forms of task-induced fatigue may differ in their effects on driver performance and safety (Neubauer et al., 2012; Saxby et al., 2013). (Desmond et al., 2001) defined active and passive fatigue, which reflect different types of workload regulation. Active fatigue, which is more typical during driving refers to the state change resulting from “continuous and prolonged, task-related psychomotor adjustment”, whereas passive fatigue develops when there is a requirement for “system monitoring with either rare or even no overt perceptual-motor requirements”. Such passive fatigue may be induced by driving in low-workload conditions, which require infrequent use of the controls (especially if cruise control is engaged), but continued vigilance for hazards (Saxby et al., 2013). Human factors studies found that passive fatigue may not affect a measure of vehicle control, but it can reduce driver's alertness and increase crash probability (Saxby et al., 2013). The usage of in-vehicle media can be a countermeasure to fatigue, but such media may also be distracting (Matthews et al., 2019). Distracted driving is dangerous and sometimes can be fatal.

(Louie & Mouloua, 2019) found that distracted drivers were significantly slower at braking when a yellow light appeared and during sudden braking events in a simulated driving study compared to non-distracted drivers. Working memory capacity moderates the impairing effect of distraction, where individuals with lower capacity are more vulnerable to the impairment (Louie & Mouloua, 2019). Neider and his colleagues conducted a series of studies focusing on older adults and found that older adults are more prone to performance impairment in multitasking situations even during everyday activities such as crossing a street (Neider et al., 2011; Gaspar et al., 2013). (Tice et al., 2020) conducted a human factors study with regards to aging and the color of express lane delineators and found that wider lane widths and buffer areas are needed to accommodate for drivers ages 65+.

Human Factors related to dms can be broken down into three (3) different components that use the Highway Safety Manual's (HSM) definition of human factors: "guidance, navigation, and control." Pertaining to the DMS, the goal is to improve guidance, reduce the burden of driver navigation, and enhance driver control.

2.3.1 Guidance

The HSM defines guidance as "the driver's ability to interact with other vehicles and execute maneuvers based on the position of the other vehicles." Examples of guidance can include but are not limited to passing, merging, staying within one's lane, maintaining a safe distance between vehicles, and driver information processing. Out of all the examples of guidance listed, information processing is the most critical aspect of the driving task. Information can be broken into two (2) types of processing: top-down and bottom-up (Matthews et al., 2008). Top-down processing refers to relevant knowledge of a previous situation that applies to the present situation (Weller et al., 2006). For example, a vehicle is passing someone on the right, the driver who is being passed can assume that the person will merge left in front of them. Bottom-up information processing refers to relying on the current situation alone without the presence of any other experience. An example of this would be driving in snow for the first time.

As with respect to dms, FDOT has implemented messages such as "be visible, no tailgating" or "don't tailgate, keep a safe distance." Furthermore, the Highway Safety Manual describes positive guidance considering the driver's limitations and expectations. Pictograms are a type of positive guidance, which makes the driver able to comprehend a high load of information in a brief period that would otherwise be impossible if presented in words. (Luoma & Rämä, 2001) conducted a study to evaluate whether drivers would accurately comprehend pictograms on DMS and found that pictograms by themselves were open to misinterpretation if not presented contextually with words, therefore creating an information overload on the driver with regards to comprehension. In addition, (Zhong et al., 2012) looked at guidance compliance behaviors obtained from drivers reading DMS. They discovered that multiple demographic factors, including driving experience, average annual miles driven per year, education level, income, and occupation influenced guidance compliance from the DMS.

2.3.2 Navigation

Navigation is the driver's ability to follow a path from origin to destination using guide signs and landmarks (HSM, 2010). Route choice is a significant component of driver's navigation, and drivers rely heavily on DMS during navigation. (Wardman, Bonsall, & Shires, 1997) Studied how route choice was influenced by various traffic conditions such as delay, road conditions ahead, and relative travel times during normal conditions and found that delay time was the deciding factor that influenced route choice and navigation decisions. In addition, DMS can be used to alert drivers about any potential changes in a route due to a closed road ahead. (Erke et al., 2007) evaluated whether dms would influence the route of drivers when a message was displayed on the sign versus no message displayed on the sign and found that roughly one (1) in five (5) vehicles changed routes due to the message.

2.3.3 Control

Control is defined as the ability of the driver to maintain an appropriate speed and keep the vehicle in the lane (HSM, 2010). Speed choice is a major human factor that falls under the control aspect of the driving task. Speed choice can be affected by the driver's surroundings and the distance of objects from the vehicle. Moreover, weather conditions can influence the control aspect of the driving task. (Rämä & Kulmala, 2000) investigated whether DMS influenced driver control and speed in wet conditions and found that the warning signs for slippery road conditions decreased driving speed by 1-2 km/h.

Control can also be influenced by the amount of driver support and assistance that exists in a vehicle. (Mouloua et al., 2004) designed a study to see if the amount of driver support would decrease the amount of driver error in the vehicle compared to complete driver control and found that a "16% in steering wheel reversal rate, 15% in the standard deviation of steering wheel angle) was needed to realize improved safety performance (e.g., 11% in peak lateral error)."

2.4 Dynamic Message Signs (DMS)

2.4.1 Overview

DMS are a tool used to convey information to drivers, including route choices, travel time, crash information, and other messages that remind drivers to obey the law and stay safe. The MUTCD, chapter 2L, outlines the appropriate DMS standards and guidelines. These guidelines include the DMS' applications, the design characteristics, and the message length. There are two major types of DMS which consists of temporary and permanent. These are used for different purposes. Temporary DMS or Portable Changeable Message Signs (PCMS) are primarily implemented on Maintenance of Traffic (MOT) projects, whereas the permanent DMS is used primarily on expressways to alert drivers with real-time traffic alerts.

2.4.2 MUTCD Applications and Design Characteristics

As per section 2L.02 of the MUTCD, DMS are used for 11 major applications. An example of an application that DMS is used for is travel times (Meehan, 2005). Travel times can also display pictograms of a road if there is a state or interstate shield, as shown in **Figure 2-2**.

Figure 2-2: DMS Showing Travel Time on I-95

This section also outlines that DMS may be used for other applications such as displaying AMBER alert messages and other transportation-related emergencies, providing that the display format shall not be a type used in advertising displays (MUTCD, 2009). Section 2L.03 of the MUTCD describes the legibility and visibility standards pertaining to the DMS. (Upchurch et al., 1991) evaluated target value, legibility, and viewing comfort using flip disk, light-emitting diode (LED), and fiber optic. The fiber optic outperformed the LED lights with respect to the target value, legibility distance, and viewing comfort. Legibility can also be affected by the text size and the driver's speed. (Ullman et al., 2005) compared text size on dms in different time of day conditions using a 9-inch text size versus a 10.6-inch text size. They found that the 10.6-inch text size during the daytime had a higher legibility distance than the 9-inch legibility distance during daytime and nighttime scenarios. Section 2L.04 states that the minimum letter height on dms for speeds less than 45 miles per hour should be 12 inches and 18 inches for speeds of 45 miles per hour or greater. Furthermore, this section states that any text size larger than 18-inches will not increase legibility distance.

The State of Florida currently has design standards for dynamic message signs, including the cantilever and span structures, the DMS itself, and the catwalk detail (FDOT, 2021). FDOT lists these standards following Standard Plan Index (SPI) 700-040, 700-041, 700-090, and SPI 700-091. These standards have been developed in accordance with MUTCD, section 2L. In addition, Florida requires every DMS to comply with the criteria of the National Electrical Manufacturers Association (NEMA TS4-2016) as stated in section 700-4.1 of the FDOT Standard Specifications Handbook. The State of Florida also goes above the minimum standards set by the MUTCD and requires all DMS to have a catwalk for maintenance purposes. This catwalk shall comply with SPI 700-091 and section 700-4.1, subsections one (1) through three (3) in the FDOT Specifications Handbook. **Figure 2-3** shows the current configuration of dms that complies with SPI 700-041 and SPI 700-090.

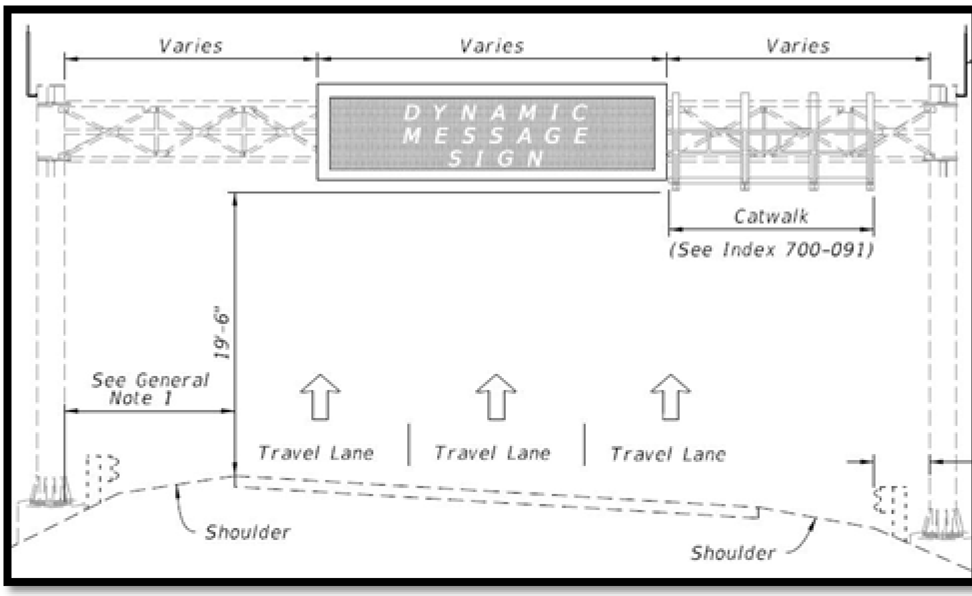


Figure 2-3: FDOT DMS in Accordance with SPI 700-041/SPI 700-090

2.4.3 DMS Types

Dynamic message signs can be split up into two (2) types: temporary and permanent. Temporary signs involve any portable message sign. Permanent signs will reside in the same location and are not used for construction purposes. On the one hand, A PCMS is a type of temporary DMS used primarily for MOT purposes. The FDOT Standard Specifications Manual states that a PCMS shall have no more than two (2) phases and up to three (3) lines, with no more than eight (8) characters per line. In addition, the text size for a PCMS shall comply with section 2L.04 of the MUTCD. Due to these standards provided by FDOT and the MUTCD, abbreviations on PCMS are often used to convey information to drivers using as few characters as possible. (Hustad & Dudek, 1999) conducted a human factors study to determine whether 85% of the population understood the proposed abbreviation on the PCMS and found that only proper noun abbreviations were not well understood by drivers outside the study region. A similar study was conducted to see if phrases on a PCMS were interpreted by 85% or more of the drivers as part of a Texas DOT project, and the researchers did not recommend to the Texas DOT any messages that did not meet this threshold (Durkop & Dudek, 2001).

On the other hand, permanent signs are primarily used on expressways to alert drivers with information about driving conditions, alerts, or events such as an accident. Moreover, these types of DMS can remind drivers to stay safe and follow traffic laws. (Jamson, 2007) conducted a driving simulator study to identify if drivers would modify their driving habits pertaining to on specific reminder messages on DMS such as "Watch your speed." The study found that these advisory messages improved driver alertness without changing their driving behavior.

2.5 Impacts on DMS

2.5.1 Safety

Traffic safety is the science of mitigating crashes and the measures used to prevent them (Shinar, 2017). The risk threshold model is a crucial component involved in traffic safety and was first introduced by Klebelsberg (1977). This model involves two (2) key components being objective and subjective safety. Objective safety refers to the driver's physical environment, while subjective safety is the perception of how the driver feels in that environment. For example, suppose subjective safety is greater than objective safety. In that case, a situation can be deemed safe to a driver because the driver perceives the situation to be more dangerous than it truly is.

On the contrary, a dangerous situation would occur if objective safety exceeded subjective safety. (Wilde, 2002) proposed a similar situation and found that drivers would adjust their risk threshold based on a scenario such as passing a driver or merging. Drivers would also adjust their risk tolerance levels to other scenarios if they remained under the driver's accepted level of risk (Panou et al., 2007).

DMS play a crucial role in traffic safety to reduce crashes to serve as a crash reduction factor. The HSM defines a Crash Reduction Factor (CRF) as the percentage of crashes reduced to a proposed measure implemented in the field. (Elvik et al., 2009) conducted a meta-analysis that determined the CRF for installing "crash ahead" DMS led to a 44% reduction in crashes on freeways that applied to incapacitating, non-incapacitating, and possible injuries. In addition, the HSM defines the KABCO scale and lists the associated costs per type of crash on this scale. (Donaldson & Kweon, 2018) evaluated whether DMS would serve as an effective crash reduction tool and a countermeasure for deer-vehicle collisions along Interstate 64. They found that during the service life of the DMS, $595,500 to $1.2 million could be saved, which is the equivalent of two (2) to four (4) incapacitating crashes (HSM, 2010).

Distance, height, and placement of dms is an essential factor for traffic safety (FDOT Standard Plans, 2021). For example, (Yan & Wu, 2014) looked at various driving behavior factors that influenced the placement of dms and found that dms should be placed between 150 and 200 meters (500 feet and 650 feet) for optimal traffic safety.

2.5.2 Reaction Time and Cognitive Performance

Reaction time is defined as the ability to notice a stimulus and react to it (Kosinski, 2008). In terms of traffic safety, a decreased reaction time is optimal. Various factors can influence reaction time, and these include light intensity, the size of the stimulus, and the duration of the stimulus presented to the subject. Regarding dms, the text size, the length of the message, message content, and the color of the text can all influence reaction time. For example, (Ma et al., 2016) conducted a study regarding comprehension of dms and whether reaction time would be lowered with the varying difficulty of message content and found that overall comprehension increased by 16% and reaction time decreased by an average of 0.39 seconds as the complexity of message content increased. In addition, (Kersavage et al., 2020) evaluated to see if the colored background of DMS as well as the color of the font would influence the reaction time and found that drivers reacted the quickest when the messages were only displayed on a black background as compared to any other color. Reaction time is also related to cognitive performance, which is the ability of a driver to withstand the workload, stress, and fatigue that one must undergo to have the clarity to comprehend a message.

The cognitive performance also involves brain function, and which parts of the brain are the most active. For example, cognitive performance directly correlates with the amount of oxygenated hemoglobin in the brain, specifically in the prefrontal cortex region (Ferrari and Quaresima, 2012; Harrivel et al., 2013). Oxygenated hemoglobin is a protein that transports oxygen to the brain inside the blood, while the prefrontal cortex lies in the brain's frontal region on the surface. For instance, (Shealy et al., 2020) looked at how brain activity influenced the way drivers interpreted and reacted to non-traditional DMS by using functional near-infrared spectroscopy and found that the non-traditional safety messages presented on DMS are just as effective as the traditional messages. In addition, (Khan 2020) evaluated non-traditional DMS to see whether behavioral data and cognitive performance would impact the driver and discovered that driver behavior was more influenced by traditional messages over non-traditional messages in terms of statistical significance.

2.5.3 Traffic Operations

Traffic operations are the science of maintaining proper flow, speed, and density (Banos, et al., 2017). Concerning dms, traffic operations revolve around the level of service (LOS) and delay on a freeway segment, which is a direct way to categorize traffic flow as a function of density. Accidents can affect both the delay and LOS on a freeway. (Tay & De Barros, 2008) noted that the public perception of DMS on a freeway could positively impact the LOS. In addition, (Benson, 1996) noted that DMS are “simple, reliable and useful” and that demographics have a minor impact on the perception of the DMS, except for the level of education an individual has.

2.6 SUMMARY AND CONCLUSIONS

The literature review included both the theoretical and applied studies on the effects of dms concerning the driver’s behavior. The studies included different types of measures, tools used to execute the study, and the DMS effect on the driver. While some of these studies have reported significant effects of the DMS influencing the driver’s behavior regarding reaction time, driving speed, comprehension, and legibility distance, others have failed to obtain such effects. In addition, some of the effects of the DMS on driver behavior were also moderated by individual factors such as participants’ gender, age, or education level. The discrepancy in the results could be partially attributed to the lack of experimental control. Based on these studies, a matrix (taxonomy) has been developed, as shown in **Table 2-1**. This taxonomy highlights the effects of the DMS regarding legibility, comprehension, speed, and other contributing factors. The table is organized based on: Study methodology (driving simulator, field observations, survey questionnaires, etc.), measures used (what question was the researcher trying to answer), the effect of the DMS from the measure used (answer to the research question), whether the type of data were objective or subjective (based on real-time data or the participant's opinion), whether the data were statistically significant (if objective data were used), and if so, what was the P-value of that data? In general, P-value less than 5% is considered significant.

Based on the taxonomy results presented in **Table 2-1**, several factors are involved in the relationship between dms and driver behavior. This taxonomy highlights the importance of various task characteristics, environmental factors, testing platforms, and individual variables that are relevant for the assessment of dms on driver behavior. In addition, the literature review also showed that the effects dms on driver behavior were not consistent. A total of 21 studies were selected for inclusion in the initial coding and analysis of various task characteristics, testing platforms, and individual variables described above. About 52% of the evaluated studies (laboratory, field observations, and driving simulator experiments) reported significant effects of the DMS influencing the way a driver behaves, while three (3) studies (14%) failed to obtain such effects, six (6) studies (29%) used subjective data such as survey data, and therefore did not mention any statistical significance, and one (1) study (5%) did use field data, but the statistical results were not mentioned.

Table 2-1: Taxonomy of the Effects of DMS on Driving Behavior

Author(s)	Study Methodology	Measures	Effect(s) from DMS	Objective/Subjective Data	Statistically Significant/different (Yes/No)	P-Value
Jeihani & Ardeshiri (2013)	Driving simulator	Driving speed & route choice	Reduction in speed	Subjective (surveys) & objective (driving simulator data)	Yes (null rejected)	Not mentioned
Khan (2020)	Driving simulator	Speed, distance between vehicles, & texting behavior	Reduction in speed & increase in distance from vehicles	Subjective (surveys) & objective (driving simulator data)	Yes	0.0001, <0.0001, & 0.0001
Shealy et al. (2020)	Laboratory Experiment	Cognitive response (fNIRS)	Improved driver behavior of safe driving messages compared to aggressive driving	Objective (fNIRS)	Yes	<0.001
Edquist et al (2011)	Driving simulator	Driver distraction (gaze time) from the eye tracking device	N/A (billboards were studied)	Objective (driving simulator & eye tracking data)	No	N/A
McAvoy (2011)	Driving simulator & eye tracking device	Speed, lane position, deceleration, & average fixation time	Reduction in speed, no impact on lane position, & significant deceleration	Objective (driving simulator & eye tracking data)	Yes/No	<0.001, N/A, <0.001, & N/A

Author(s)	Study Methodology	Measures	Effect(s) from DMS	Objective/Subjective Data	Statistically Significant/different (Yes/No)	P-Value
Hardy et al., 2006	Field observations	Animal-vehicle collisions, spot speed data, & traffic volume	Signs did not influence driver behavior	Objective (field data)	No	N/A
Luoma & Rämä (2001)	Survey questionnaires	Message types & message symbols	A red triangle was perceived as a warning by most drivers	Subjective (surveys)	N/A	N/A
Zhong et al. (2012)	Survey questionnaires	Route choice	Improved guidance & route choice	Subjective (surveys)	N/A	N/A
Wardman, Bonsall, & Shires (1997)	TV screen & survey questionnaires	Route choice	Delay from the DMS influenced route choice	Subjective (demographic data)	N/A	N/A
Erke et al., 2007	Field observations	Route choice, speed, & braking behavior	Increased route diversion from DMS, lowered speed, & increased braking behavior	Objective (field data)	Yes	<0.001, <0.001, & 0.001
Rämä & Kulmala (2000)	Field observations	Speed reduction on slippery roads	Speed was reduced due to the presence of the DMS	Objective (field data)	Yes	<0.05

Author(s)	Study Methodology	Measures	Effect(s) from DMS	Objective/Subjective Data	Statistically Significant/different (Yes/No)	P-Value
Upchurch, Armstrong & Hadi (1991)	Field observations	Target value, legibility, & viewing distance based on lighting type and time of day	Target value, legibility & viewing distance was influenced by TOD and lighting conditions	Objective (field data)	Not mentioned	Not mentioned
Ullman et al. (2005)	Test vehicle	Legibility distance due to text size	Larger text increased legibility distance	Subjective (demographic data) & objective (test vehicle data)	N/A (t-test not used)	N/A
Hustad & Dudek (1999)	Survey questionnaires	Comprehension of abbreviations	85% of the participants must have comprehended the abbreviation for it to be recommended	Subjective (surveys)	N/A	N/A
Durkop & Dudek (2001)	Survey questionnaires	Comprehension of abbreviations	85% of the participants must have comprehended the abbreviation for it to be recommended	Subjective (surveys)	N/A	N/A

Author(s)	Study Methodology	Measures	Effect(s) from DMS	Objective/Subjective Data	Statistically Significant/different (Yes/No)	P-Value
Jamson (2007)	Driving Simulator	Speed, headway, & gaze time	The content of safety messages was not beneficial to changing the speed, headway, and gaze time	Objective (driving simulator data)	No	N/A
Elvik et al. (2009)	Meta-analysis	Reduction in crashes	The "crash ahead" message reduced crashes by 44%	Objective (previous study data)	Yes	0.05 (From CMF Clearing-house website)
Donaldson & Kweon (2018)	Field observations	Number of deer-vehicle collisions & speed data	Reduction in speed & savings in property damage	Objective (field data)	Yes	Not mentioned
Yan & Wu (2014)	Driving simulator	Route choice, speed, & lane-changing behavior	DMS placement influenced route choice, reduction in speed upon approach, & DMS influenced lane changing position	Subjective (demographic data) & objective (driving simulator data)	Yes	0.009, Not mentioned, & 0.001

Author(s)	Study Methodology	Measures	Effect(s) from DMS	Objective/Subjective Data	Statistically Significant/different (Yes/No)	P-Value
Ma et al., 2016	Driving simulator	Message comprehension, distraction level, & self-reported level of difficulty	increased comprehension with driver complexity & decreased reaction time	Subjective (self-reported level of difficulty) & objective (driving simulator data)	Yes	0.003, <0.001, & 0.001
Kersavage et al., 2020	Laboratory experiment	Reaction time due to wording, texts, background colors, & colored fonts	Messages that displayed time only had the shortest reaction time	Objective (computer data)	Yes	0.03

Overall, the results of this taxonomy showed a consensus in supporting the effects of dms on driver behavior in a driving simulator. Five (5) out of the seven (7) simulation studies reported significant effects on driving speed, lane position, and deceleration. However, with regards to field observations, two (2) out of the five (5) studies that were included had significant effects from the DMS on driving behavior, where one (1) of the studies did not mention if their data were statically significant. These findings clearly indicate that the driving simulator may serve as a strong and suitable method for investigating the effects of dms on driver behavior, particularly when driving in an interstate setting. Furthermore, the literature findings also identified the most studied parameters, including the environmental factors, driving behavior factors, and participants' individual demographics. Therefore, based on the literature review results, a driving simulator experiment was designed to investigate the effects of DMS with respect to driver behavior using different factors such as time of day (TOD), traffic density or level of service (LOS), and message content that included traditional, informative, and humorous. The messages that were used were taken from an approved list from FDOT's Highway Signing Program (HSP). The HSP had a list of approved messages that consists of categories that were applicable to freeways and multilane arterials, arterials only, weather or emergency situations, and holiday/special events. Both bio-behavioral measures consisting of drivers' attention responses, driving performance accuracy, and eye movements were recorded in a series of simulated driving environments. These measures included vehicle speed, deceleration, and lane changing behavior from the driving simulator, while first fixation time, perception-reaction time, and time to first notice (TTFN) were identified from the eye-tracking device. Finally, the results of this research effort will serve as a benchmark to determine which type of message is suitable for each traffic condition or TOD condition. Findings from this research will have both theoretical and practical implications for the assessment of message type, driver behavior, roadway design, and traffic safety.

III. RESEARCH PLAN AND DESIGN OF EXPERIMENT (DOE)

This task explains the procedures and protocols needed to design a driving simulator experiment to evaluate different message types on driver behavior in preparation for the actual experiment in Task 3.

3.1 Institutional Review Board (IRB)

Review and approval are required for all research involving human participants conducted by the University of Central Florida (UCF) through the Institutional Review Board (IRB). Approval must be obtained prior to including human participants in an investigation to ensure that the guiding ethical principles for human subject protection are met All members of the research team involved in the design, conduct, or reporting of the research must complete a "Human Subjects Research-Group and Social/Behavioral Research Investigators" training. A specific protocol needs to be developed which includes the study procedure, inclusion and exclusion criteria, number of subjects, recruitment methods, potential benefits and/or risks to subjects as well as data management and confidentiality.

Participants are screened for eligibility using an OPTEC machine. They also must go through a series of surveys to identify any motion or simulation sickness before, during and after the experiment. A specific protocol is designed, and a consent form will be given to each participant to explain the process of the research and obtain their approval. Both bio-behavioral measures will be recorded in a series of simulated driving environment. The experiment includes several procedures which are explained in detail in the following sections. The IRB approval process took approximately three (3) months. The IRB approval letter and protocol are provided in **Appendix A** of this report.

3.2 Equipment

3.2.1 Driving Simulator

The study will utilize a driving simulator as well as an eye tracking system. The driving simulator, which is located at the University of Central Florida Institute of Simulation and Training (UCF-IST) department, as shown in **Figure 3-1** will be utilized for the experiment and data collection. The UCF IST driving simulator provides a high-fidelity driving testing environment. It includes a visual monitor (one 55” flat panel display), a quarter-cab of actual vehicle hardware including a steering wheel, pedals, adjustable seat, and shifter from a real vehicle, a digital sound simulation system and a central console. The seat is independent of the driving simulator itself, but it is directly connected to the simulator. The simulator exports data to an external hard drive that will always remain in the IST lab. The exported data consists of the inputs of the gas pedal, brake pedal, and steering wheel recorded during the experiment.

Figure 3-1: UCF IST Driving Simulator

3.2.2 Eye Tracking System (FOVIO Eye-tracker)

An eye tracking system is also utilized in this study. Eye movements will be recorded using the FOVIO eye-tracker using the Eyeworks software as shown in **Figure 3-2**. This low-profile enclosed system mounts inconspicuously on the dashboard. It offers fast calibration for research subjects and improved eye tracking especially for nighttime conditions. The device uses a camera that does not involve an invasive process of calibration and allows free head movement without attaching anything to the participant. An infrared camera is placed below the computer screen at the participant's workstation to track where the participants' eyes are focused. Eye movement data are acquired in realtime with multiple metrics including blink rate, fixation frequency, fixation durations, saccades, scan path, and pupil diameter. Analysis of the frequency of fixations within a pre-specified Area of Interest (AOI) will be used to determine how participants allocate their attention to the safety messages. The eye-tracking computer has an infrared tracking processor which samples the data at a rate of 60 Hz. The eye tracking data will be exported from Eyeworks and stored on a secure hard drive.

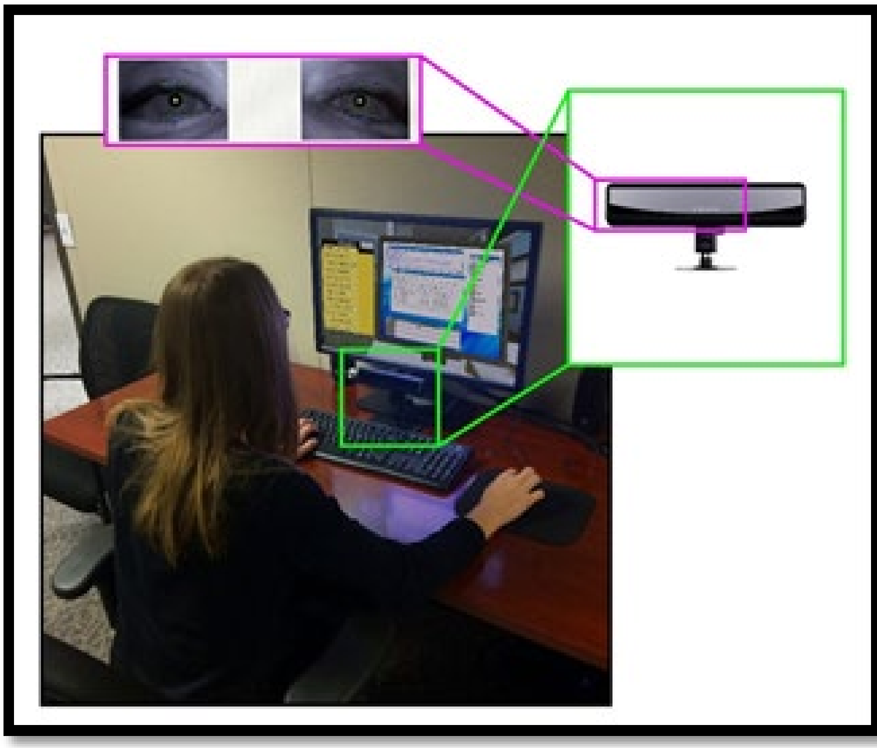


Figure 3-2: Fovio Eye Tracker and Pupillary-Corneal-Corneal Reflection Tracking Software

3.3 Participants

At least 90 drivers, who have valid driver licenses, will be selected to participate in the experiment. The subjects' ages will range from 18 to over 65. Since most of the variables of interest in this study are based on the participants' demographics, a nice even distribution will need to be met to ensure unbiased results. Therefore, a variety of subjects with varying age, gender, education, ethnicities, and backgrounds will be recruited. Participants will run the simulations through voluntary means and are free to withdraw from the simulation at any time and from partaking in the study for any reason. To ensure the minimum number of 90 participants is achieved, the sample size will be increased by 20% to account for any participant's attrition. The distribution of the participants' age and gender is shown in **Table 3-1**.

Table 3-1: Participants' Demographics Based on the Number and Gender

Age Group	Gender	
	Male	Female
Between 18 and 34	15	15
Between 35 and 64	15	15
65+	15	15

3.4 Recruitment process

Identifying potential participants will not be a difficult task for this research because the main requirements are to be above 18 years old with a valid driver's license and must not have a history of severe motion sickness. The participants who meet the age requirement must go through a preliminary screening test without issues such as individuals who have at least 20/40 normal or corrected visual acuity. For those who cannot pass the screening test or violate the traffic rules on purpose will be excluded. A monetary incentive of $50 will be provided for each participant who will complete the experiment scenarios. The UCF Psychology Research Participation System (SONA) will also be utilized as explained in the following section where students can earn extra credits in their course work or choose to get the $50.

The family and friends of the researchers will be recruited by word of mouth or by e-mail. Older adults will be recruited through the Learning Longevity Research Network (LLRN) via e-mail. Likewise, faculty and staff will also be recruited by word of mouth or by e-mail. A description will be given to explain the basis of the research and will be sent out through these e-mails. In addition, flyers will be sent out of the campus to companies, as well as religious institutions in the Orlando area. These flyers will also be posted on social media to help advertise the study. The advertisement and sample email are attached in **Appendix B**.

3.4.1 SONA Systems

SONA Systems is the University of Central Florida's online research participation system for the Psychology Department. This system provides undergraduate UCF Psychology students a way to easily view and sign up for studies within or partnering with the psychology department. In return for volunteering their time participating in a study registered on SONA Systems, individuals typically receive extra credit in one of their Psychology courses. However, the $50 gift card can be used instead of course credit if requested by the participant. The SONA system will be helpful in recruiting the younger age easily.

3.4.2 Learning Longevity Research Network

The Learning Longevity Research Network (LLRN) is a database comprised of contact information for older adults who are interested in participating in research conducted at the University of Central Florida in the greater Orlando, Florida area. This network allows researchers at the University of Central Florida to email older adults in the database about research participation opportunities that may be of interest to the individual. The LLRN database will facilitate recruitment of the older age group.

3.5 Experiment Protocol

Upon arrival, all participants will be asked to read and sign an informed consent form per IRB to make sure each participant knows what to expect. Then, each participant will be asked to take a demographic survey including questions on the variables of interest (age, gender, etc.), before they enter the driving simulator room. In addition, the participant must fill out the following pre-task surveys: Driver Stress Inventory (DSI), Driving Behavior Questionnaire (DBQ), Stanford Sleepiness Scale, and the Dundee Stress State Pre-Task Questionnaire (DSSQ-Pre). It should be noted that participants who are 65 and older will be screened for cognitive impairment using a Mini-Mental State Examination (MMSE). The pre-task surveys are included in **Appendix C**. The participant will be screened for motion sickness before and after the study and will also be monitored to make sure they do not become motion sick using Kennedy et al.'s Simulator Sickness Questionnaire (SSQ) which is attached in **Appendix D**. If the participant becomes motion sick, they will be provided water and a cool place to sit, until their motion sickness subsides as defined by the SSQ. The motion sickness will be monitored by the research assistants who will watch for signs of uneasiness.

Driving simulator systems may induce a variety of simulation/virtual reality sickness symptoms (e.g., nausea, dizziness, and disorientation) a result of a system exposure and/or longer exposure durations, especially for the older adults who may be more susceptible to simulation sickness

(SS) than their younger counterparts. If such extreme cases happen, the experimental protocols will be adjusted accordingly to reduce the effects of such SS symptoms.

Before starting the driving simulator scenarios, each participant will take a short training session, including the Traffic Regulation Education, the Safety Notice, and the Familiarity Training. In the Traffic Regulation Education session, all participants are advised to drive, follow traffic rules, and behave as they normally do in real driving situations. In addition, participants will not be informed about the details of the experiment specifically dynamic message signs before the experiment. In the Safety Notice session, each participant will be told that they can quit the experiment at any time if they have any motion sickness symptoms or any kind of discomfort. In the Familiarity Training session, each participant is given about 10 minutes training to familiarize them with the driving simulator operation, such as straight driving, acceleration, deceleration, left/right turns, and other basic driving behaviors.

After completing the short training session, participants will start the formal experiment and go through **16** different scenarios in a random sequence to eliminate the time order effect. In addition, all participants are recommended to rest couple of minutes between the scenarios.

After completing all the scenarios, each participant will complete a series of post-task questionnaires, including an exit survey to determine whether they noticed the message signs and to get their opinion on the most attention-grabbing message. The post task questionnaires are included in **Appendix E** and the exit survey is included in **Appendix F**. The summary of the procedure is shown in **Table 3-2**. The total anticipated time duration of each participant in the experiment is around 100 minutes. It should be noted that all surveys will be administered electronically through the Dujo software developed by the IST department, and all Covid-19 guidelines will be followed.

Table 3-2: Procedure Summary

No.	Procedure	Time duration
1	Complete initial surveys (Demographic survey, DSI, SSQ, DSSQ-Pre, MMSE (65+))	20 mins
2	Practice scenario (Traffic regulation education, safety notice, and familiarity training)	10 mins
3	Formal experiment (16 runs, including two SSQ)	60 mins
4	Additional surveys (including exit survey)	10 mins

3.6 Design of Experiment

3.6.1 Scenario Matrix

In many scientific investigations, the concern is to optimize the system. Experimentation is one of the popular activities used to understand and/or improve a system. This can be achieved by studying the effects of two or more factors on the response at two or more values known as "levels" or settings simultaneously. This type of standard experiment is known as factorial design. Cost and practical constraints must be considered in choosing factors and levels. Therefore, two-level factorial designs are common for factor screening in industrial applications. However, if a nonstandard model is required to adequately explain the response or the model contains a mix of factors with different levels, the experiment results in an enormous number of runs. In this study, the parameters consist of three (3) two-level factors and one (1) four-level factor. The standard number of full factorial design needed to cover all cases would amount to 32 (2^3*4^1) runs for each applicant. The factors (levels) are time of day (daytime, nighttime), traffic density (low, high), message type (traditional, creative), and message category (work zone, speeding, visibility, maneuvering). For 100 applicants, the total would be 3,200 runs. Under such conditions and to minimize the number of runs for each participant, optimal custom designs are the recommended design approach. Choosing an optimality criterion to select the design points is another requirement. Accordingly, the D-optimality and l-optimality criteria are the two custom designs employed for this experiment.

Optimal designs fall under two main categories. One is optimized with respect to the regression coefficients (d-optimality criteria) and the other is optimized with respect to the prediction variance of the response (I-optimality criteria). D-optimal designs are more appropriate for screening experiments because the optimality criterion focuses on estimating the coefficients precisely. The D-optimal design criterion minimizes the volume of the simultaneous confidence region of the regression coefficients when selecting the design points. This is achieved by maximizing the determinant of X'X over all possible designs with specific number of runs. Because the volume of the confidence region is related to the accuracy of the regression coefficients, a smaller confidence region means more precise estimates even for the same level of confidence. Therefore, this experiment will utilize the d-optimal design.

Table 3-3 provides the layout of the scenario matrix which describes the experimental plan in terms of the study factors.

Table 3-3: Scenario Matrix

No.	TOD	Traffic Density	Message Type	Message Category
1	Night	Low	Traditional	Work Zone
2	Day	High	Creative	Maneuvering
3	Night	Low	Creative	Speeding
4	Day	High	Traditional	Visibility
5	Day	Low	Creative	Speeding
6	Day	High	Creative	Work Zone
7	Day	Low	Traditional	Speeding
8	Night	Low	Traditional	Speeding
9	Night	High	Creative	Visibility
10	Day	High	Creative	Visibility
11	Night	Low	Creative	Maneuvering
12	Day	High	Traditional	Work Zone
13	Night	High	Traditional	Visibility
14	Night	Low	Traditional	Maneuvering
15	Night	Low	Creative	Work Zone
16	Day	High	Traditional	Maneuvering

Each participant of the 100 will go through the 16 scenarios for a total of 1,600 runs. Each row of the table represents one set of experimental conditions that when run will produce a value of the response variable.

The response variable entails both bio-behavioral measures consisting of drivers' attention responses, driving performance accuracy, and eye movements. They will be recorded in a series of simulated driving environments, where vehicle speed, deceleration, and lane changing behavior will be extracted from the driving simulator, while time to first notice (TTFN), legibility distance, perception-reaction time, and average gaze duration will be identified from the eye tracking device.

3.6.2 Driving Simulator

The driving simulator software used to create the scenarios was STISIM. Additional softwares were utilized to develop the DMS signs. These included Maya and 3D Max. STISIM was used to create the roadway, pavement markings, and other features such as speed limit signs, buildings, and trees within the scenario.

The models and signs were developed by the University of Central Florida Institute for Simulation and Training (IST) group. **Figure 3-3** shows the creation of the DMS signs in the 3d Max software.

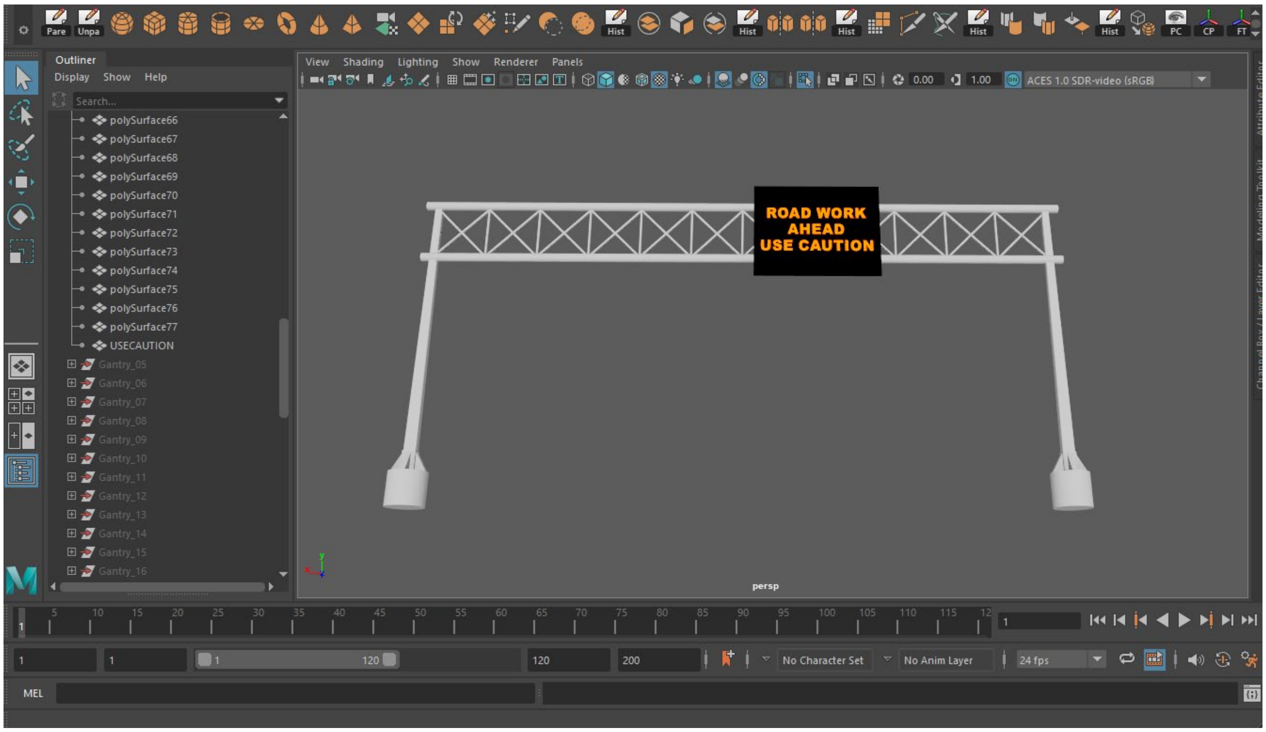


Figure 3-3: Creation of DMS Sign in 3D Max Software

The model includes one static object representing the DMS. The model contains two (2) message options: Traditional and Creative. The dimensions of the DMS are constructed according to FDOT SPI 700-090. The plans do not specify an exact width or height of the DMS and specify it as "varies", but based on the figures provided from the index, a width of 24 feet and a height of 6 feet was used for the DMS, with half of the DMS over the entire middle lane and the other two quarters of the DMS over half of outer and inner lanes as shown in **Figure 3-4**. The span of the DMS is constructed to comply with FDOT SPI 700-041.

In addition, STISIM was used to create the three (3) 12-foot lanes per direction and the pavement markings that are compliant with Chapter 3 of the MUTCD and FDOT SPI 711-001. The scenario also contains features consistent with an urban environment with a center Type K barrier, lighting spaced at 200-foot intervals on both sides of the road, and 8-foot paved shoulders.

Figure 3-5 shows a snapshot of the driving simulator scenario with a traditional work zone related DMS sign during Daytime conditions and **Figure 3-6** shows a nighttime scenario with a creative work zone related message.

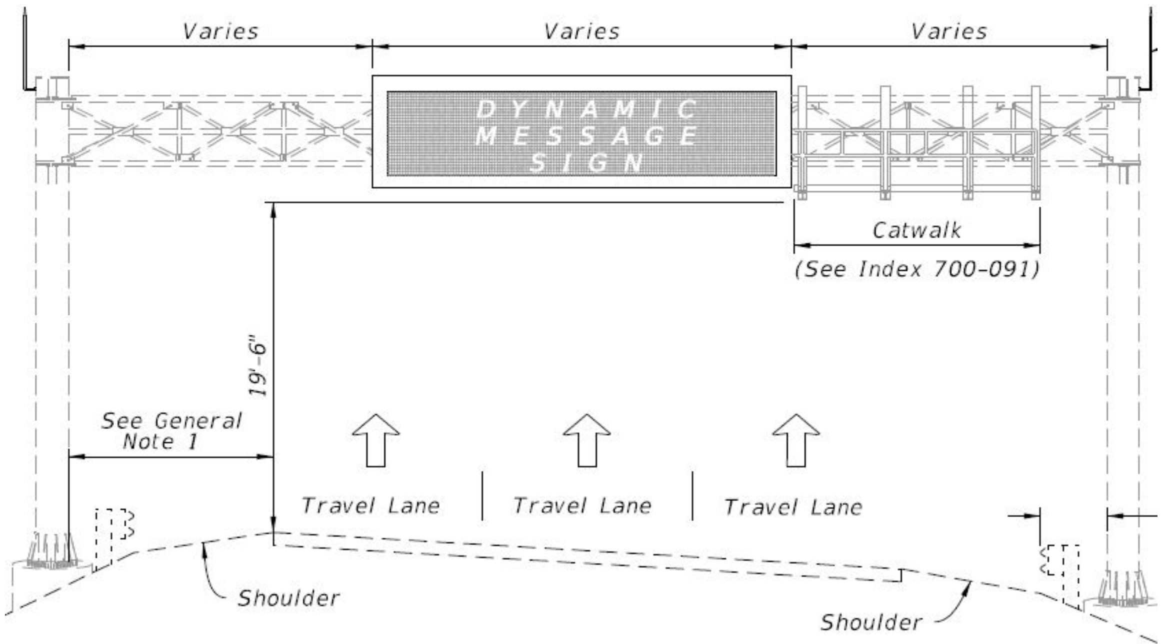


Figure 3-4: Dynamic Message Sign with Dimensions from FDOT SPI 700-090

Figure 3-5: Daytime Scenario Showing a Traditional Work-Zone-Related Message

Figure 3-6: Nighttime Scenario Showing a Creative Work-Zone-Related Message

The model consists of a 6-lane section throughout the whole scenario with a DMS sign placed after a mile from the starting point. The DMS will be in accordance with FDOT SPI 700-090.

In order to measure the behavioral response for each message, a specific scenario will be created after each message. For example, **Figure 3-7** shows an example for a construction zone scenario which will be added after the work-zone related messages. The total length of each scenario is between two and three (2-3) miles. **Figure 3-8** shows a sample of the approved creative messages which are obtained from FDOT Topic 000-750-015.

Figure 3-7: Added Construction Zone Scenario in the Driving Simulator

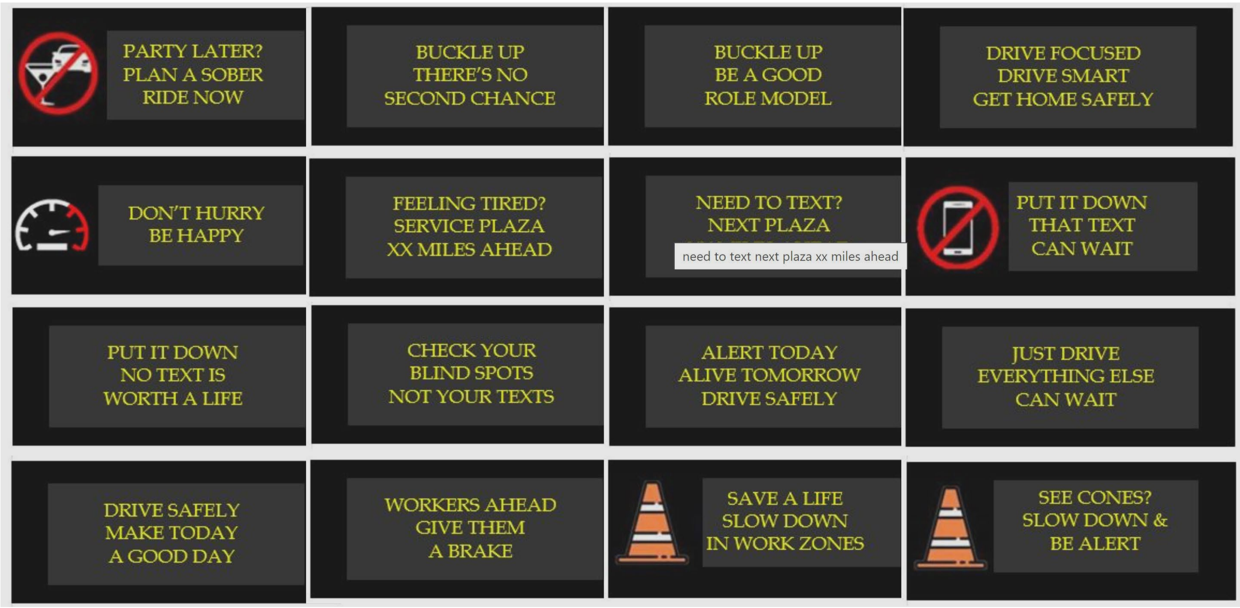


Figure 3-8: Sample of FDOT Approved Creative Messages

Each participant will be asked to drive the total length of the scenario to experience all conditions. The speed limit is 65 mph, and the driving speed of the participants will depend on the traffic density. Participants will take approximately three (3) minutes to finish each scenario.

As mentioned earlier, there are two (2) main factors that are included in the design of experiment in addition to the message type and message category that can influence the driving behavior. The factors are time of day and traffic density. Time of day includes daytime and nighttime, and traffic density refers to low and high traffic densities ranging from 5 to 30 vehicles per lane per mile, respectively.

The data will be examined at several locations in the scenario. The locations will start at a quarter of a mile before the DMS. Data collection will include the experiment sampling time, vehicle speed, acceleration, deceleration, lane changes, vehicle position, and steering angle. The data will also be complemented with the eye movement, time to first notice (TTFN) and areas of attention. **Table 3-4** shows all the 16 messages that are selected to be tested in the 16 scenarios along with the proposed scenarios and parameters needed to measure the behavioral response. **Appendix G** includes all the 16 dynamic message signs used in the driving simulator scenarios.

Table 3-4: Scenario Matrix with Displayed Messages and Added Scenarios

Sc#	TOD	Traffic Density	Message Type	Message Category	Displayed Message	Added Scenario After Message	Behavioral Response Measured
1	Night	Low	Traditional	Work Zone	ROAD WORK AHEAD USE CAUTION	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
2	Day	High	Creative	Maneuvering	ITS NOT A RACE, LEAVE SOME SPACE	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed
3	Night	Low	Creative	Speeding	DONT HURRY BE HAPPY	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
4	Day	High	Traditional	Visibility	HEAD LIGHTS ON WHEN RAINING IT'S THE LAW	Reduce Visibility by introducing Rain	Change in Speed (1 if driver turned on lights, otherwise 0)
5	Day	Low	Creative	Speeding	WARP SPEED IS FOR SPACE TRAVEL SLOW DOWN	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
6	Day	High	Creative	Work Zone	SEE CONES? SLOW DOWN & BE ALERT	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
7	Day	Low	Traditional	Speeding	SPEED LIMIT ENFORCED	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
8	Night	Low	Traditional	Speeding	OBEY SPEED LIMIT	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
9	Night	High	Creative	Visibility	VISIBILITY LOW? DRIVE SLOW	Reduce Visibility by introducing Fog	Change in Speed
10	Day	High	Creative	Visibility	WHEN RAINING BE BRIGHT SWITCH ON LIGHTS	Reduce Visibility by introducing Rain	Change in Speed (1 if driver turned on lights, otherwise 0)
11	Night	Low	Creative	Maneuvering	ITS CALLED A TURN SIGNAL USE IT	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed (1 if driver turned on signal, otherwise 0)
12	Day	High	Traditional	Work Zone	SLOW DOWN FOR VEHICLES ON THE SHOULDER	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
13	Night	High	Traditional	Visibility	FOG REDUCED VISIBILITY	Reduce Visibility by introducing Fog	Change in Speed
14	Night	Low	Traditional	Maneuvering	SIGNAL BEFORE CHANGING LANES	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed (1 if driver turned on signal, otherwise 0)
15	Night	Low	Creative	Work Zone	WORKERS AHEAD GIVE THEM A BREAK	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
16	Day	High	Traditional	Maneuvering	DON'T TAILGATE KEEP A SAFE DISTANCE	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed

IV. HUMAN FACTORS EXPERIMENT

This task explains the human factors experiment, procedures and protocols used to recruit the participants for the driving simulator experiment prior to the evaluation process in Task 4.

4.1 Revised Institutional Review Board (IRB) and Project Extension

Review and approval of the protocol and procedures required for the human factors experiment were obtained by the research involving human participants conducted by the Institutional Review Board (IRB) to ensure that the guiding ethical principles for human subject protection are met All members of the research team involved in the design, conduct, or reporting of the research completed a "Human Subjects Research-Group and Social/Behavioral Research Investigators" training. A specific protocol was developed which includes the study procedure, inclusion and exclusion criteria, number of subjects, recruitment methods, potential benefits and/or risks to subjects as well as data management and confidentiality. A specific protocol is designed, and a consent form was given to each participant to explain the process of the research and obtain their approval.

A no-cost time extension was approved by FDOT, and the project schedule was extended till end of March 2023 with Task 3 due by the end of October 2022 for two main reasons. First, the recruitment efforts of participants were delayed due to COVID. These efforts have improved and been completed for the younger age group; however, additional time is needed to recruit participants from the oldest age group during the upcoming Fall semester. Second, due to different revisions to task 2 deliverable related to the experimental design and scenario development and receiving the final approval. The no-cost time extension form, and the revised IRB approval are included in **Appendix A**.

4.2 Equipment

4.2.1 Driving Simulator

The study utilized a driving simulator as well as an eye tracking system. The driving simulator located at the University of Central Florida Institute of Simulation and Training (UCF-IST) department, as shown in **Figure 4-1** was utilized for the experiment and data collection. The UCF IST driving simulator provides a high-fidelity driving testing environment. It includes a visual monitor, one 55" flat panel LED HDR display (resolution: 3840 * 2160), a quarter-cab of actual vehicle hardware including a steering wheel, pedals, adjustable seat, and shifter from a real vehicle, a digital sound simulation system and a central console. The seat is independent of the driving simulator itself, but it is directly connected to the simulator. The simulator exports data to an external hard drive that hosts the experiment data. The exported data consisted of the participants behavioral inputs of the gas pedal, brake pedal, and steering wheel recorded during the experiment.

Figure 4-1: UCF IST Driving Simulator

4.2.2 Eye Tracking System (FOVIO Eye-tracker)

An eye tracking system was also utilized in this study. Eye movements were recorded using the FOVIO eye-tracker using the Eyeworks software as shown in **Figure 4-2**. This low-profile enclosed system mounts inconspicuously on the dashboard. It offers fast calibration for research subjects and improved eye tracking especially for nighttime conditions. The device uses a camera that does not involve an invasive process of calibration and allows free head movement without attaching anything to the participant. An infrared camera was placed below the computer screen at the participant's workstation to track where the participants' eyes are focused. Eye movement data were acquired in realtime with multiple metrics including blink rate, fixation frequency, fixation durations, saccades, scan path, and pupil diameter. Analysis of the frequency of fixations within a pre-specified Area of Interest (AOI) was used to determine how participants allocate their attention to the safety messages. The eye-tracking computer has an infrared tracking processor which samples the data at a rate of 60 Hz. The eye tracking data were also exported from Eyeworks and stored on the secure hard drive.

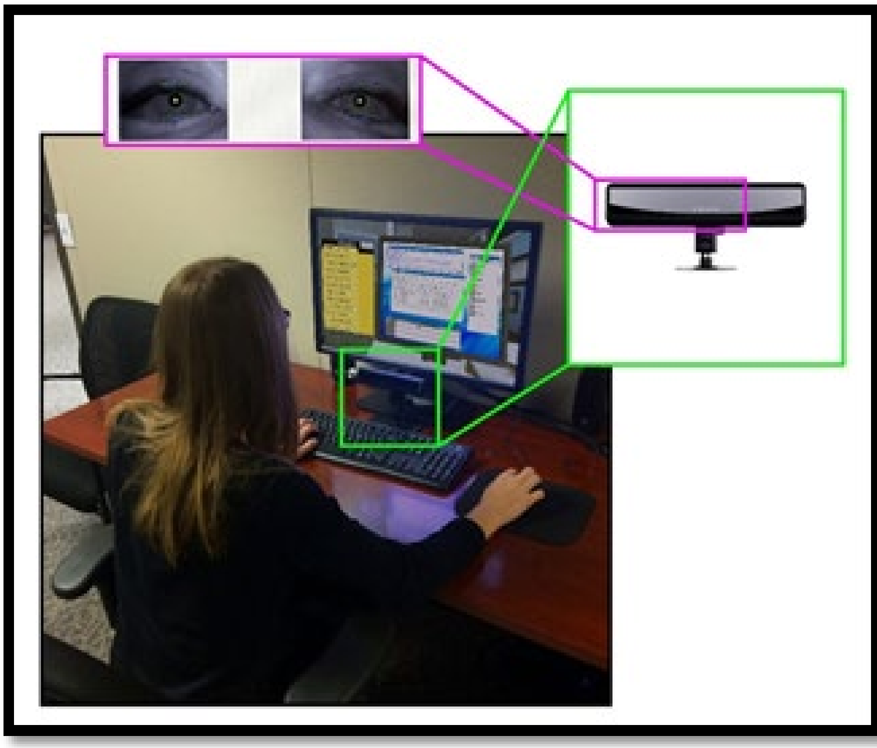


Figure 4-2: Fovio Eye-Tracker and Pupil/Corneal Reflection Tracking Software

4.3 Participants

A total of 97 participants were recruited to participate in the study through a variety of mechanisms, which included student recruitment (UCF SONA), Learning Longevity Research Network (LLRN), Learning Institute For Elders (LIFE), social media outreach, fliers, and personal connections. Participants were required to have normal vision and be over the age of 18. It should be noted that five (5) participants did not show up for the experiment. Therefore, the total number of participants that actually completed the experiment was **92**. The participants had valid driver licenses, with varying age, gender, education, ethnicities, and backgrounds which was recorded in the demographic surveys. The distribution of the participants' age and gender is shown in **Table 4-1**.

Table 4-1: Participants' Demographics Based on Age

Age Group	Gender	
	Male	Female
Between 18 and 34	16	15
Between 35 and 64	15	15
65+	15	16

4.4 Recruitment process

The recruitment process was a little bit challenging especially the middle age group. Due to the current programs at UCF for young age and older age groups, their recruitment process was not difficult. The participants who met the age requirement went through a preliminary screening test without issues such as individuals who have at least 20/40 normal or corrected visual acuity. A monetary incentive of $50 was provided for each participant who completed the 16 experiment scenarios. The UCF Psychology Research Participation System (SONA) was utilized as explained in the following section where students can earn extra credits in their course work or choose to get the $50.

Older adults were recruited through the Learning Longevity Research Network (LLRN) via e-mail. Likewise, family and friends of the researchers were recruited by word of mouth or by e-mail as well as faculty and staff. In addition, flyers were sent out to companies as well as religious institutions in the Orlando area. These flyers were also posted on social media to help advertise the study. The advertisement flyer and sample email are attached in **Appendix B**.

4.4.1 SONA Systems

SONA Systems is the University of Central Florida's online research participation system for the Psychology Department. The purpose of this program is to give students an opportunity to participate in the experimental process as a part of their grade. Students have a wide range of experiments to choose from but are required as part of these classes to participate in a minimum number of hours for each class. This was one of the primary methods used to recruit participants from the 18-34 age group and therefore many were between 18 and 22 years of age. Class credit was given to any SONA student that attempted the experiment whether they completed the study or not. However, the $50 gift card can be used, instead of course credit if requested by the participant. The SONA system was very helpful in recruiting the younger age easily. Nearly all the participants in this age group were recruited using this system.

4.4.2 Learning Institute for Elders (LIFE)

The Learning Longevity Research Network (LLRN) and the Learning Institute For Elders (LIFE) University are two programs at UCF that support senior adults with ongoing learning activities. The LLRN has a website and an email database of senior adults that are available for aging research. LIFE University is a 501c3 organization created by UCF that provides weekly learning opportunities for adults 50 and over in a university setting. This network allows researchers at the University of Central Florida to email older adults in the database about research participation opportunities that may be of interest to the individual. The chair of the LIFE program was contacted to explain the research experiment. A form was filled out with all experiment information and a representative from the UCF research team was invited to one of their weekly meetings to explain the research process prior to signing up. The LIFE meeting facilitated the recruitment of the older adults group. Most of the participants aged 65+ in this study were recruited from the LIFE program.

4.4.3 Social Media

To augment recruitment for the 35–64-year-old demographic group, several social media platforms were used which included Facebook and Linked-In. The local Central Florida Institute of Transportation Engineers (CFITE) chapter also allowed us to send out a Mail Chimp advertisement to their members. Many of the working-age participants were recruited from this source.

4.4.4 Flyers

A flyer was used during the course of the experiment to recruit the remaining participants. These flyers were placed in various public locations like Panera, barber shops, the YMCA, churches, mosques, and libraries. Very few participants were recruited using this method, although the flyers were useful for distributing contact information at events like LIFE University. Out of the three means of recruitment, this was the least effective way to obtain participants.

4.4.5 Personal Connections

Several participants were recruited from friends, family, and colleagues of the researchers. Many of the working-age participants were from this group.

4.5 Experiment Protocol

A script was developed to ensure that each researcher conducted the experiment in an unbiased and consistent manner. The script includes how to set up the simulator room before the participant arrives, the informed consent requirements, vision screening, surveys, the calibration process, the practice drive, the first two (2) practice drives (daytime and nighttime conditions), procedures the researcher needs to do during the break, the 16 scenarios, post study surveys, and cleaning up the room for the next participant.

Upon arrival, all participants were asked to read and sign an informed consent form per IRB to make sure each participant knows what to expect. Then, each participant was asked to take a demographic survey including questions on the variables of interest (age, gender, etc.), before they enter the driving simulator room. In addition, the participants filled out the following pre-task surveys: Driver Stress Inventory (DSI), Driving Behavior Questionnaire (DBQ), Stanford Sleepiness Scale, and the Dundee Stress State Pre-Task Questionnaire (DSSQ-Pre). It should be noted that participants who are 65 and older were screened for cognitive impairment using a Mini-Mental State Examination (MMSE). The pre-task surveys are included in **Appendix C**. The participants were also screened for motion sickness using Kennedy et al.'s Simulator Sickness Questionnaire (SSQ) which is attached in **Appendix D**. It should be noted that none of the participants experienced any motion sickness during the 16 scenarios.

Before starting the driving simulator scenarios, each participant took a short training session, including the Traffic Regulation Education, the Safety Notice, and the Familiarity Training. In the Traffic Regulation Education session, all participants are advised to drive, follow traffic rules, and behave as they normally do in real driving situations. The familiarity training session was about 10 minutes to familiarize them with the driving simulator operation, such as straight driving, acceleration, deceleration, left/right turns, and other basic driving behaviors.

After completing the short training session, participants started the formal experiment and went through **16** different scenarios in a random sequence to eliminate the time order effect. All participants were recommended to rest couple of minutes between the scenarios.

After completing all the scenarios, each participant completed a series of post-task questionnaires, including an exit survey to determine whether they noticed the message signs and to get their opinion on the most attention-grabbing message. The post task questionnaires are included in **Appendix E** and the exit survey is included in **Appendix F**. The summary of the procedure is shown in **Table 4-2**. The total time duration of each participant in the experiment took about 120 minutes. However, the older participants took about 30 minutes more time than the other participants. It should be noted that all surveys were administered electronically through the Dujo software developed by the IST department, and all Covid-19 guidelines were followed. **Figure 4-3** shows a participant driving one of the scenarios and completing the surveys.

Table 4-2: Experiment Procedure Duration

No	Procedure	Time Duration
1	Complete initial surveys (Demographic survey, DSI, SSQ, DSSQ-Pre, MMSE (65+))	20 mins
2	Practice scenario (Traffic regulation education, safety notice, and familiarity training)	10 mins
3	Formal experiment (16 runs, including two SSQ)	80 mins
4	Additional surveys (including exit survey)	10 mins

Figure 4-3: Participant (a) Driving and (b) Completing Surveys

4.6 Driving Simulation Scenarios Development

4.6.1 Scenario Matrix

In this study, the parameters consisted of three (3) two-level factors and one (1) four-level factor. The factors (levels) are Time of Day (Daytime, Nighttime), Traffic Density (Low, High), Message Type (Traditional, Creative) and Message Category (Work Zone, Speeding, Visibility, Maneuvering). Each participant of the 92 went through the 16 scenarios for a total of 1,472 runs. Each row of the table represents one set of experimental conditions that produced a value of the response variable.

Table 4-3 provides the layout of the scenario matrix which describes the experimental plan in terms of the study factors, message types, added scenarios and behavioral data measured.

Table 4-3: Scenario Matrix

Sc#	TOD	Traffic Density	Message Type	Message Category	Displayed Message	Added Scenario After Message	Behavioral Response Measured
1	Night	Low	Traditional	Work Zone	ROAD WORK AHEAD USE CAUTION	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
2	Day	High	Creative	Maneuvering	ITS NOT A RACE, LEAVE SOME SPACE	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed
3	Night	Low	Creative	Speeding	DONT HURRY BE HAPPY	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
4	Day	High	Traditional	Visibility	HEAD LIGHTS ON WHEN RAINING IT'S THE LAW	Reduce Visibility by introducing Rain	Change in Speed (1 if driver turned on lights, otherwise 0)
5	Day	Low	Creative	Speeding	WARP SPEED IS FOR SPACE TRAVEL SLOW DOWN	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
6	Day	High	Creative	Work Zone	SEE CONES? SLOW DOWN & BE ALERT	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
7	Day	Low	Traditional	Speeding	SPEED LIMIT ENFORCED	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
8	Night	Low	Traditional	Speeding	OBEY SPEED LIMIT	Place a Lower Speed Limit Sign with No Visible Reason to Slow Down	Response Time & Change in Speed
9	Night	High	Creative	Visibility	VISIBILITY LOW? DRIVE SLOW	Reduce Visibility by introducing Fog	Change in Speed
10	Day	High	Creative	Visibility	WHEN RAINING BE BRIGHT SWITCH ON LIGHTS	Reduce Visibility by introducing Rain	Change in Speed (1 if driver turned on lights, otherwise 0)
11	Night	Low	Creative	Maneuvering	ITS CALLED A TURN SIGNAL USE IT	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed (1 if driver turned on signal, otherwise 0)
12	Day	High	Traditional	Work Zone	SLOW DOWN FOR VEHICLES ON THE SHOULDER	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
13	Night	High	Traditional	Visibility	FOG REDUCED VISIBILITY	Reduce Visibility by introducing Fog	Change in Speed
14	Night	Low	Traditional	Maneuvering	SIGNAL BEFORE CHANGING LANES	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed (1 if driver turned on signal, otherwise 0)
15	Night	Low	Creative	Work Zone	WORKERS AHEAD GIVE THEM A BREAK	Add a Construction Zone with Cones and workers on the Right	Change in Speed and Possible Lane Change
16	Day	High	Traditional	Maneuvering	DON'T TAILGATE KEEP A SAFE DISTANCE	Vehicle infront Slows Down/Brakes Sharply	Headway, Spacing, Response Time, Time to Collision & Change in Speed

The response variable entails both bio-behavioral measures consisting of drivers' attention responses, driving performance accuracy, and eye movements. They were recorded in a series of simulated driving environments, where vehicle speed, deceleration, and lane changing behavior were extracted from the driving simulator, while time to first notice (TTFN), legibility distance, perception-reaction time, and average gaze duration were identified from the eye tracking device.

4.6.2 Roadway Layout

The total length of the roadway was set to 2 miles (or 10560 feet) with no curvature. Three 12-foot lanes per direction and the pavement markings that are compliant with Chapter 3 of the MUTCD and FDOT SPI 711-001 were developed. The scenario also contains features consistent with an urban environment (e.g., buildings and trees) with a center Type K barrier, lighting spaced at 200-foot intervals on both sides of the road, and 8-foot paved shoulders. the roadway was divided into six (6) blocks 0.25 miles each denoting the speed limit signs, DMS and the added scenario locations to facilitate the data extraction process as shown in **Figure 4-4**. This roadway design applies to all simulation scenarios including practice and experimental scenarios.

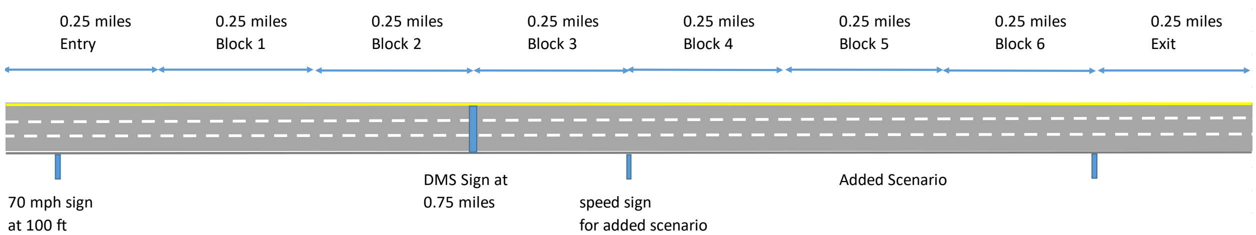


Figure 4-4: Roadway Layout and Blocks Configuration

4.6.3 Driving Scenarios

A total of sixteen (16) experimental simulation scenarios were developed based on the study design and scenario matrix proposed in Task 2 report as shown in Table 3. In addition to the experimental simulation scenarios, two practice scenarios were developed for training and practice purposes. All simulation scenarios were programmed using the official scripting language of STISIM driving simulation, the Scenario Definition Language (SDL). The programmed scenarios were implemented on the STISIM driving simulator for data collection. The simulation was run on a custom-built desktop with Intel® Core™ i7-7700K CPU @ 4.2 GHz and 16 GB RAM using Windows 10 Enterprise operating system. Detailed information regarding each scenario is provided in the following sections according to the message categories defined previously.

a) Practice scenarios

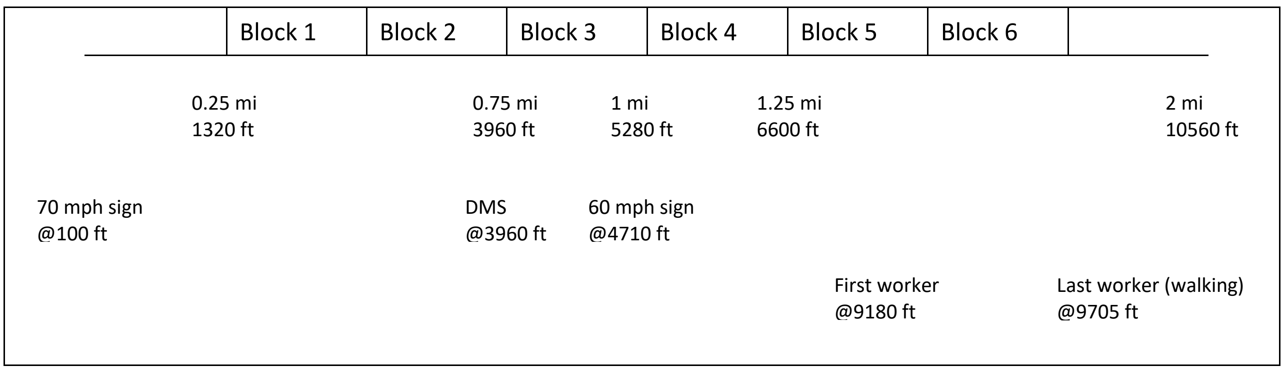
Two practice scenarios were developed to allow participants to familiarize themselves with the simulated environment and controls before the experimental scenarios. Two factors, time of day and traffic density, were manipulated in the practice scenarios. Practice Scenario 1 was set to be in the daytime with high traffic density and Practice Scenario 2 was set to be in the night with low traffic density in most of the scenarios. In the high traffic density condition, there were a total of 210 vehicles (209 simulation-controlled vehicles and 1 participant-controlled vehicle) whereas in the low traffic density condition, there were a total of 60 vehicles (59 simulation-controlled vehicles and 1 participant-controlled vehicle). The simulation-controlled vehicles were randomized in models and selected from a library of vehicles offered by STISIM. The speed limit was set to 70 mph at the beginning of the 2-mile highway section.

b) Work zone scenarios

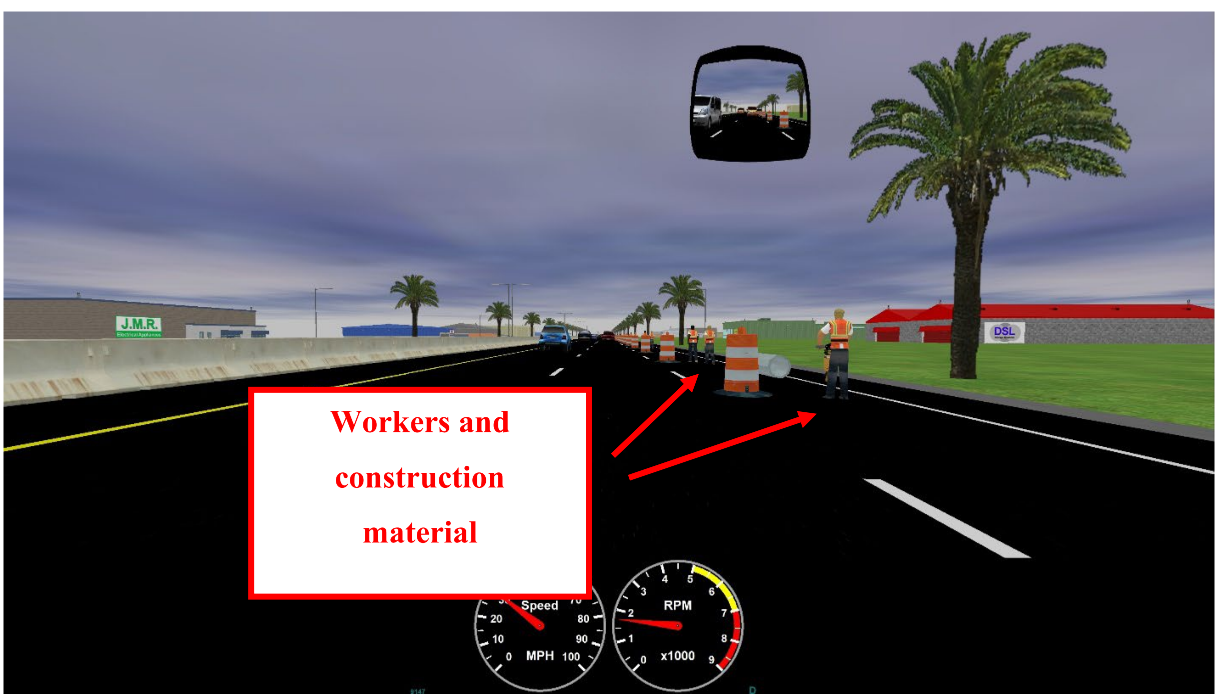
Four experimental scenarios (Scenario 1, 6, 12, and 15) varying in time of day, traffic density, and message type were developed with work zone related messages displayed on the DMS. The work zone related messages were selected from FDOT Topic 000-750-015. The DMSs with work zone related messages varying in message type (i.e., traditional vs. creative) were placed at 0.75 mi (or 3960 ft) down the road in each scenario. An added event with cones and workers on the right lane and a reduced speed limit was introduced after the DMS. The reduced speed limit sign of 60 mph was added at 4710 ft. The first cone appeared at 8220 ft after warning signs such as road work ahead, right lane closed ahead, and merge sign that are compliant with FDOT standards. Thirteen workers wearing reflective vests and helmets (1 stationary worker and 12 moving workers) and some construction materials (e.g., concrete pipes) were added in the work zone in the cone blocked lane. The first worker (stationary) appeared at 9180 ft and the last worker started walking at 9705 ft towards the same travel direction of the participant-controlled vehicle at the speed of 4 ft/sec. The simulation-controlled vehicles on the right lane were programmed to merge into either the left or the middle lane when approaching the work zone. **Table 4-4** and **Figure 4-5** show work zone scenarios design information.

Table 4-4: Work Zone Scenarios

Message	Message Type	Time	Traffic	Sc#	Word#
SLOW DOWN FOR VEHICLES ON THE SHOULDER	Traditional	Day	High	12	7
SEE CONES? SLOW DOWN & BE ALERT	Creative	Day	High	6	7
ROAD WORK AHEAD USE CAUTION	Traditional	Night	Low	1	5
WORKERS AHEAD GIVE THEM A BREAK	Creative	Night	Low	15	6



(a) Roadway Layout



(b) Daytime Scenario

(c) Nighttime Scenario

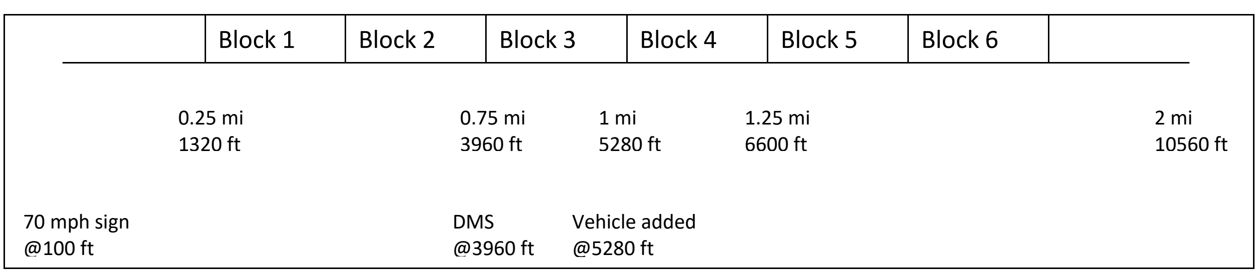
Figure 4-5: Work Zone (a) Layout, (b) Daytime, and (c) Nighttime Scenarios

c) Maneuvering scenarios

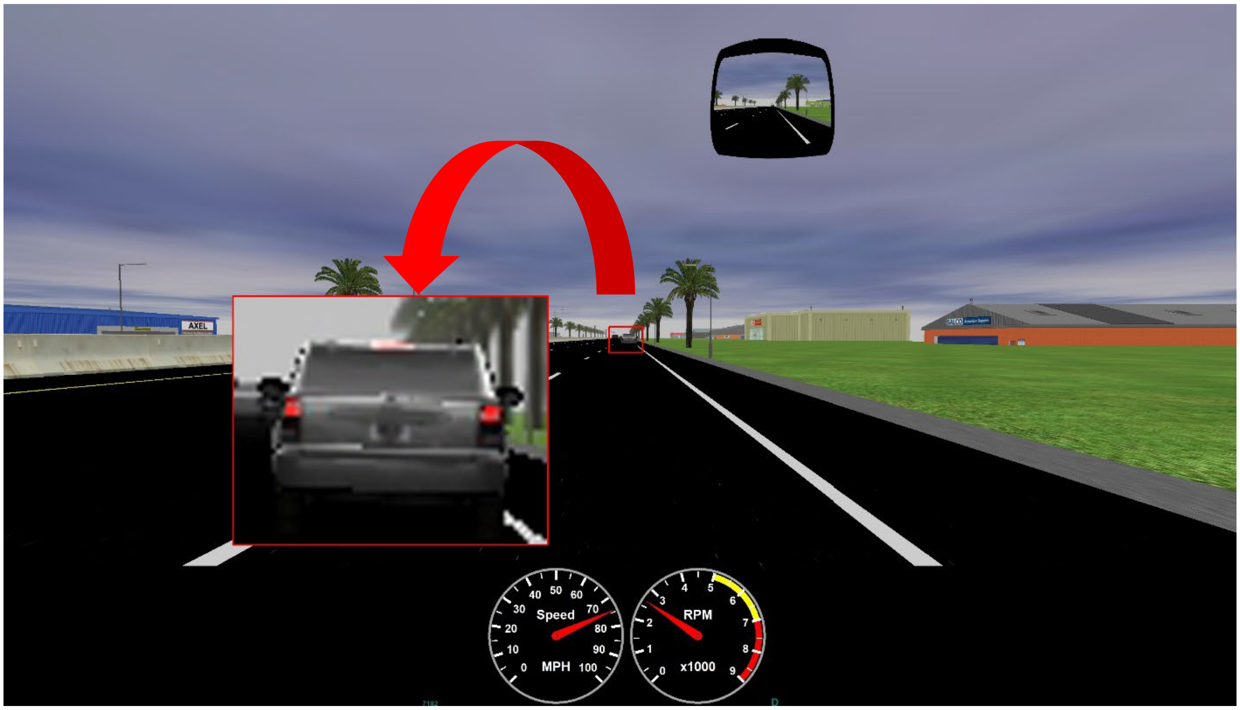
Four experimental scenarios (Scenario 2, 11, 14, and 16) varying in time of day, traffic density, and message type were developed with maneuvering-related messages displayed on the DMS. The simulation-controlled vehicle added later in the scenario was a silver mid-sized SUV. The speed limit was set to 70 mph at the beginning of the 2-mile highway section. The DMSs with maneuvering-related messages varying in message type (i.e., traditional vs. creative) were placed at 0.75 mi (or 3960 ft) down the road in each scenario. An added event was introduced after the DMS: The simulation-controlled vehicle slowed down in front of the participant-controlled vehicle. An additional simulation-controlled vehicle was added to maneuvering scenarios at 5280 ft down the road. When the participant-controlled vehicle was traveling to 500 ft behind the added vehicle, the vehicle's speed changes to 80% of the participant-controlled vehicle's current speed and kept changing as the participant-controlled vehicle's speed changed so that participants could catch up with the added vehicle eventually. Meanwhile, the added vehicle merges to match the participant-controlled vehicle's lane position so that the added vehicle is always in front of the participant-controlled vehicle. When the participant-controlled vehicle travels to 200 ft behind the added vehicle, the added vehicle brakes and slows down to 30% of the participant-controlled vehicle's current speed with brake lights illuminated. After the brake event, the simulation-controlled vehicle's lane position is unlocked from the participant-controlled vehicle's lane position to allow any necessary maneuvering performed by participants. In addition, after the brake event, the added vehicle will change the speed back to the normal speed, which is 70 mph, and switch off its brake lights. Detailed maneuvering scenarios design information is shown in **Table 4-5** and **Figure 4-6**.

Table 4-5: Maneuvering Scenarios

Message	Message Type	Time	Traffic	Sc#	Word#
DON'T TAILGATE KEEP A SAFE DISTANCE	Traditional	Day	High	16	6
ITS NOT A RACE, LEAVE SOME SPACE	Creative	Day	High	2	7
SIGNAL BEFORE CHANGING LANES	Traditional	Night	Low	14	4
ITS CALLED A TURN SIGNAL USE IT	Creative	Night	Low	11	7



(a) Roadway Layout



(b) Daytime Scenario

(c) Nighttime Scenario

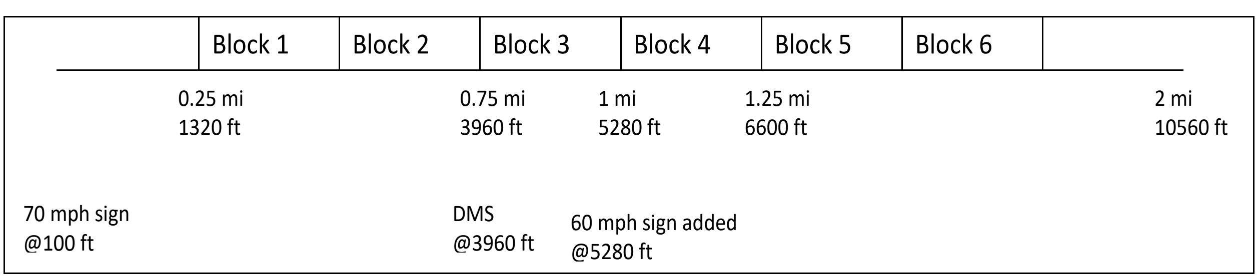
Figure 4-6: Vehicle Slowing Down (a) Layout, (b) Daytime, and (c) Nighttime Scenarios

d) Speeding scenarios

Four experimental scenarios (Scenario 3, 5, 7, and 8) varying in time of day and message type were developed with speeding related messages displayed on the DMS. All four speeding scenarios were set to have low traffic density. The speed limit was set to 70 mph at the beginning of the 2-mile highway section. The DMSs with speeding related messages varying in message type (i.e., traditional vs. creative) were placed at 0.75 mi (or 3960 ft) down the road in each scenario. An added event with a lower speed limit sign was introduced after the DMS. Two reduced speed limit signs of 60 mph were added at 5280 ft on both sides of the road. The road condition was kept consistent throughout the entire scenario. There was no visible reason (e.g., work zone, slow traffic, accident, etc.) to slow down except the added lower speed limit signs. Detailed speeding scenarios design information are shown in **Table 4-6** and **Figure 4-7**.

Table 4-6: Speeding Scenarios

Message	Message Type	Time	Traffic	Sc#	Word#
SPEED LIMIT ENFORCED	Traditional	Day	Low	7	3
WARP SPEED IS FOR SPACE TRAVEL SLOW DOWN	Creative	Day	Low	5	8
OBEY SPEED LIMIT	Traditional	Night	Low	8	3
DONT HURRY BE HAPPY	Creative	Night	Low	3	4



(a) Roadway Layout

(b) Daytine Scenairo

(c) Nighttime Scenario

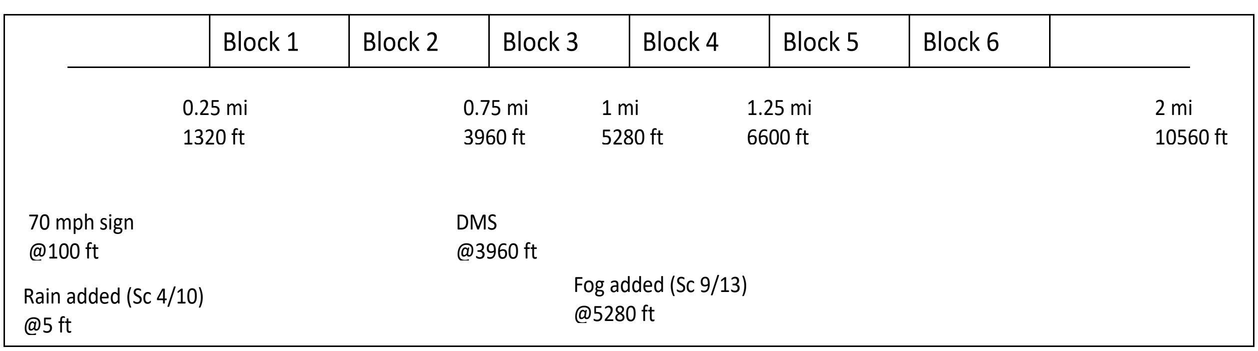
Figure 4-7: Reduced Speed Limit Signs (a) Layout, (b) Daytime, and (c) Nighttime Scenarios

e) Visibility scenarios

Four experimental scenarios (Scenario 4, 9, 10, and 13) varying in time of day and message type were developed with visibility related messages displayed on the DMS. All four visibility scenarios were set to have high traffic density. The speed limit was set to 70 mph at the beginning of the 2-mile highway section. The DMSs with visibility related messages varying in message type (i.e., traditional vs. creative) were placed at 0.75 mi (or 3960 ft) down the road in each scenario. Two environmental factors, rain, and fog were utilized in visibility scenarios to reduce the visibility. Scenarios 4 and 10 (daytime) have an added event of rain and scenarios 9 and 13 (nighttime) have an added event of fog. In the two scenarios with rain, rain was added at the beginning of the scenario (5 ft). The visibility was reduced to 500 ft. In other words, participants can only see 500 ft ahead in the rain in these scenarios. In the two scenarios with fog, the added event of fog was set to appear after the DMS at 5280 ft. The visibility in the foggy zone was 50 ft. In other words, participants can only see 50 ft ahead in the fog in scenarios 9 and 13. Detailed visibility scenarios design information are shown in **Table 4-7** and **Figure 4-8**.

Table 4-7: Visibility Scenarios

Message	Message Type	Weather	Time	Traffic	Sc#	Word#
HEAD LIGHTS ON WHEN RAINING IT'S THE LAW	Traditional	Rain	Day	High	4	8
WHEN RAINING BE BRIGHT SWITCH ON LIGHTS	Creative	Rain	Day	High	10	7
FOG REDUCED VISIBILITY	Traditional	Fog	Night	High	13	3
VISIBILITY LOW? DRIVE SLOW	Creative	Fog	Night	High	9	4



(a) Roadway Layout

(b) Daytime Scenario

(c) Nighttime Scenario

Figure 4-8: Reduced Visibility (a) Layout, (b) Rain, and (c) Fog Scenarios

4.6.4 Eye Tracking Calibration

Eye movements were tracked using FOVIO eye tracker, a desktop mounted infrared eye tracking system manufactured by Seeing Machines, running at 60 Hz. The configurations of the FOVIO eye tracker were specified and managed using Eyeworks software suite running on the simulation computer. Nine-point automatic calibration was performed for each participant prior to the experimental session to verify the configuration and tracking quality. Participants were asked to follow and focus on a red dot moving around the 55-inch display in the resolution of 3840 * 2160 with their eyes (shown in white dots) to complete the calibration. **Figure 4-9** is a sample calibration interface captured from the STISIM driving simulator. **Figure 4-10** shows a participant going through the eye tracking calibration process. The FOVIO eye tracker was designed to deliver higher performance, better accuracy, and simpler setup. Admittedly, the tracking quality may be less desirable in some circumstances, such as glare due to glasses, light pupil colors, or heavy eye makeup (e.g., mascara).

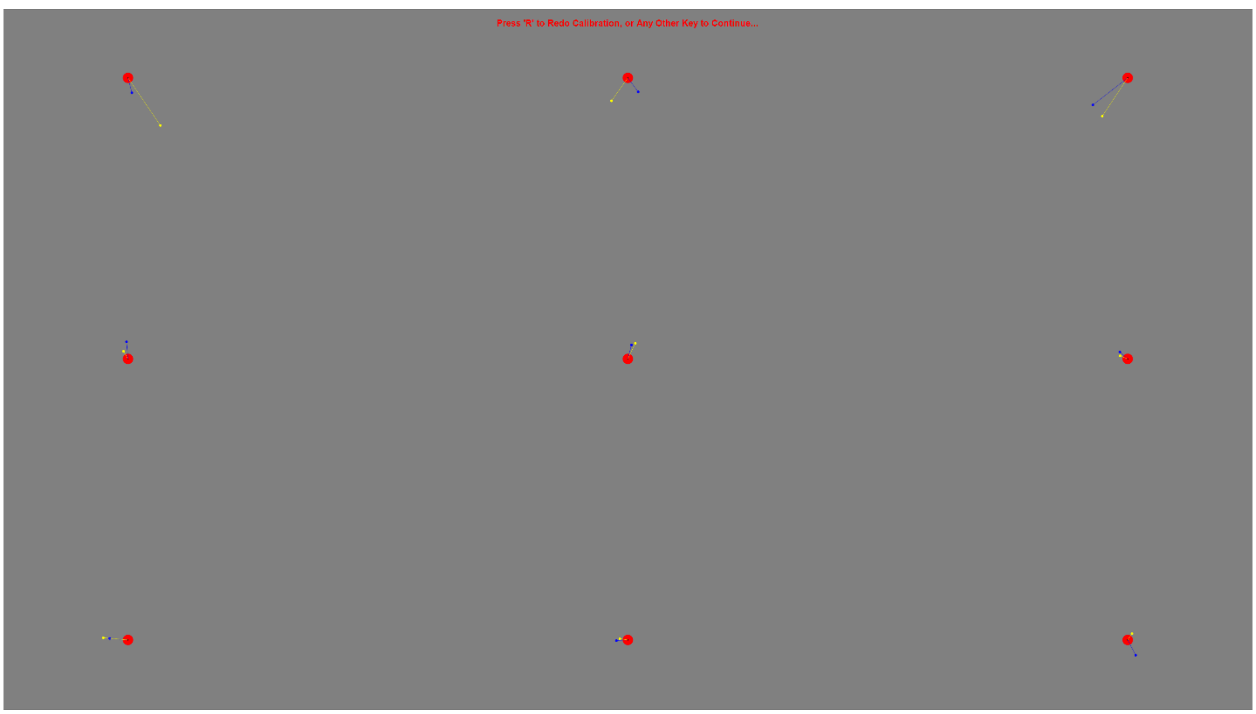


Figure 4-9: FOVIO Eye-Tracking Calibration

Figure 4-10: Participant Going through the Eye-Tracking Calibration Process

V. DATA ANALYSIS AND EVALUATION MODEL DEVELOPMENT

This task focuses on analyzing the behavioral data extracted from the driving simulator, driver visual attention data extracted from the eye tracking device and the participants' subjective responses to the surveys to understand the impacts of the creative messages on driver behavior.

5.1 Research Questions

The driving experiment consisted of several parameters and levels which included Time of Day (Daytime, Nighttime), Traffic Density (Low, High), Message Type (Traditional, Creative) and Message Category (Work Zone, Speeding, Visibility, Maneuvering). The response variables entailed both bio-behavioral measures consisting of drivers' attention responses, driving performance accuracy, and eye movements. They were recorded in a series of simulated driving environments, where vehicle speed, deceleration, and lane changing behavior were extracted from the driving simulator, while time to first notice (TTFN), legibility distance, perception-reaction time, and average gaze duration were identified from the eye tracking device. In order to evaluate the effect of the studied parameters on the response variables and reduce the data set dimensionality, the analysis was broken down into the following research questions (RQ):

RQ1: To what extent does driver visual attention vary based on message type and category, controlling for sign word length?

RQ2: To what extent does driver visual attention vary based on demographic characteristics, such as age and gender?

RQ3: To what extent does driver visual attention vary based on driving conditions, such as time of day and traffic density?

RQ4: To what extent does driver behavior differ based on message type and category, controlling for sign word length?

RQ5: To what extent does driver behavior differ based on demographic characteristics, such as age and gender?

RQ6: To what extent does driver behavior differ based on driving conditions, such as time of day and traffic density?

5.2 Behavioral Data Extraction

STISIM outputs a Data Acquisition (DAQ) file for each scenario run. The DAQ file holds records of various simulator data parameters, including acceleration, velocity, location coordinates and lane deviation. These variables were extracted into tabulated format at 60 Hz fidelity (a time-step of 1/60 seconds) using the STISIM DaqViewer script. **Table 5-1** shows excerpts from the driving data and eye tracking data used in the statistical analysis along with the participant ID, gender, age group and the different driving conditions in each scenario.

Table 5-1: Driving Data and Eye-Tracking Data Sample

Participant	Scenario ID	Word#	Block	Message Type	Message Category	TOD	Traffic Density	Age	Gender	Longitudinal acceleration	Longitudinal velocity	Lateral lane position	Steering wheel angle input	Minimum time to collision	DMSTime 2Notice	DMSFixationN _total	DMSFixationAvg Duration	DMSDwell	DMSDwell _Base	DMSDwell _All
3009	12	7	2	Traditional	Work Zone	Day	High	Old	Female	0.223435115	69.94946565	43.6532061	0.048931	7.2906107	6.2748	26	0.1986	32.4544	6.6558	19.7028
3009	13	3	2	Traditional	Visibility	Night	High	Old	Female	-0.603053435	74.20351145	44.1793893	-0.00733	8.3373282	4.2703	25	0.2188	32.8269	3.2441	8.2108
3009	14	4	2	Traditional	Maneuvering	Night	Low	Old	Female	-1.606030534	94.84770992	44.2630534	-0.05473	16.025725	1.8184	11	0.1418	20.4562	8.3604	12.0623
3009	15	6	2	Creative	Work Zone	Night	Low	Old	Female	-0.244772727	93.78280303	43.8484849	-0.07152	37.110303	10.5637	3	0.4011	10.8609	8.7591	6.4826
3009	16	6	2	Traditional	Maneuvering	Day	High	Old	Female	0.097175573	73.28320611	44.9446565	-0.0829	8.7161832	3.0207	22	0.1659	30.4169	8.5158	12.3217
3010	1	5	2	Traditional	Work Zone	Night	Low	Old	Male	0.006136364	89.09492424	43.5439394	-0.15068	22.307803	0.2933	24	0.2441	46.4151	19.3836	27.7492
3010	2	7	2	Creative	Maneuvering	Day	High	Old	Male	0.181221374	72.00709924	34.6438931	0.55855	4.2863359	0.7264	34	0.1424	35.5779	11.526	23.4295
3010	3	4	2	Creative	Speeding	Night	Low	Old	Male	0.215833333	100.3288636	42.5837879	0.149394	101.37273	2.1886	32	0.2475	50.4359	17.9238	20.4455
3010	4	8	2	Traditional	Visibility	Day	High	Old	Male	-0.637348485	60.64613636	44.8083333	0.154545	3.5667424	0.8429	13	0.1661	37.5839	1.7045	5.594
3010	5	8	2	Creative	Speeding	Day	Low	Old	Male	0.120909091	100.2669697	42.7479546	0.329697	34.811515	0.0377	41	0.1913	62.4652	19.0747	22.4982
3010	6	7	2	Creative	Work Zone	Day	High	Old	Male	0.679090909	68.79121212	44.6611364	-0.10735	4.1335606	3.2909	45	0.1835	52.8061	8.678	27.5734
3010	7	3	2	Traditional	Speeding	Day	Low	Old	Male	-0.057022901	98.47862595	43.3936641	-0.19382	69.770382	0.4429	31	0.1951	50.0341	9.6513	15.7123
3010	8	3	2	Traditional	Speeding	Night	Low	Old	Male	0.289469697	96.32106061	43.2450758	-0.21477	98.2375	0.0879	32	0.2924	47.9632	7.056	25.7235
3010	9	4	2	Creative	Visibility	Night	High	Old	Male	-1.016515152	79.98606061	42.8408333	-0.21295	11.120985	0.0816	38	0.3013	60.3926	6.737	13.9342
3010	10	7	2	Creative	Visibility	Day	High	Old	Male	0.10129771	66.64419847	44.9001527	-0.16061	5.0625191	1.6743	16	0.1831	44.4867	2.5974	5.2025
3010	11	7	2	Creative	Maneuvering	Night	Low	Old	Male	-0.594393939	98.54083333	43.6697727	-0.11583	39.774167	0.417	31	0.3032	61.2332	18.6537	24.69
3010	12	7	2	Traditional	Work Zone	Day	High	Old	Male	-0.04719697	68.48787879	39.4765152	-0.2253	5.3279545	1.2725	42	0.2061	49.6324	20.211	24.3191
3010	13	3	2	Traditional	Visibility	Night	High	Old	Male	0.189083969	70.26045802	36.191145	0.324809	3.7077099	2.3446	32	0.2499	41.9657	28.0616	13.3382
3010	14	4	2	Traditional	Maneuvering	Night	Low	Old	Male	-0.243257576	94.6755303	43.0692424	-0.11318	32.161667	1.2584	14	0.4169	38.9003	10.0568	18.01
3010	15	6	2	Creative	Work Zone	Night	Low	Old	Male	-1.754545455	76.96681818	42.5062879	0.017955	28.887803	0.3759	41	0.3393	62.7278	21.7356	33.0714
3010	16	6	2	Traditional	Maneuvering	Day	High	Old	Male	-0.420076336	69.30496183	43.689313	0.182366	5.1261069	0.3681	43	0.3136	60.2863	31.5747	34.3221
3011	1	5	2	Traditional	Work Zone	Night	Low	Old	Male	0.025151515	86.83810606	29.9101515	-0.15871	17.698106	1.7364	7	1.5053	34.6755	16.8694	14.1564
3011	2	7	2	Creative	Maneuvering	Day	High	Old	Male	0.074274809	73.70885496	30.4181679	-0.11015	8.5096183	14.0932	4	1.0004	23.4642	13.3009	12.9847
3011	3	4	2	Creative	Speeding	Night	Low	Old	Male	0.10129771	86.51671756	30.4147328	-0.06275	17.740153	11.3931	3	0.7978	22.6049	8.2725	9.8556
3011	4	8	2	Traditional	Visibility	Day	High	Old	Male	-0.013636364	74.70939394	30.4236364	0.368333	7.1997727	3.2239	4	0.2922	26.5217	4.704	6.7702
3011	5	8	2	Creative	Speeding	Day	Low	Old	Male	0.015757576	89.63681818	29.4313636	-0.10159	19.372121	8.3073	17	0.3238	32.5611	14.8418	12.7115
3011	6	7	2	Creative	Work Zone	Day	High	Old	Male	-0.145757576	76.58916667	29.7059091	0.014167	13.946364	15.1028	4	1.0523	21.1434	12.987	9.2746
3011	7	3	2	Traditional	Speeding	Day	Low	Old	Male	0.389318182	90.87916667	29.2719697	0.329015	24.587576	8.7997	3	1.0822	17.4447	10.7492	10.6439
3011	8	3	2	Traditional	Speeding	Night	Low	Old	Male	0.458625954	85.78015267	28.9226718	-0.03664	17.98313	17.3473	2	0.6039	20.1646	11.5977	9.5385
3011	9	4	2	Creative	Visibility	Night	High	Old	Male	-0.261450382	70.30099237	29.6987023	0.044351	7.2337405	20.9565	4	0.9857	17.055	4.3796	5.8344
3011	10	7	2	Creative	Visibility	Day	High	Old	Male	-0.077862595	76.15877863	42.889771	-0.01389	7.1990076	2.9176	5	0.4823	33.0435	10.7867	10.0616
3011	11	7	2	Creative	Maneuvering	Night	Low	Old	Male	-0.061136364	87.52401515	30.3189394	0.18197	18.617576	11.4876	8	0.452	25.2439	13.382	13.4292
3011	12	7	2	Traditional	Work Zone	Day	High	Old	Male	0.200909091	70.85636364	30.2856818	-0.03076	6.7882576	11.2417	5	1.0581	24.8898	10.3001	10.3986

5.3 Parameters Definitions

5.3.1 Driver Visual Attention: Eye Tracking Metrics

- **Area of Interest (AOI):** refers to the dynamic message sign (DMS) and small boundary surrounding the DMS to account for error.
- **Fixation:** Fixations were defined as a point-of-gaze lasting for a minimum duration of 0.075 seconds within a five-pixel region. The duration of each fixation is measured in seconds from the first observation in the fixation through the last observation in the fixation.
- **Time-to-Notice:** Time-to-notice refers to the elapsed time in seconds from the beginning of the task until the first fixation is recorded within the AOI.

- **Dwell Time:** Dwell time combines the number of gaze observations falling within the boundary of a specified region (AOI, the area of DMS) regardless of whether they were classified as a fixation or not.
- **Total fixation time.** Total fixation time combines all defined fixations that fall within the boundary of the specified AOI (i.e., the area of DMS). Given that total fixation time and dwell time are highly correlated, $r = .92$, subsequent results exclude the former.

Summary statistics for the eye tracking metrics are summarized in **Table 5-2**. **Figure 5-1** demonstrates the distribution of the eye tracking factors across all driving scenarios. Performance factors included time to notice, fixation and dwell times along the roadway sections.

Table 5-2: Summary Statistics for Eye-Tracking Metrics (seconds)

	N	Mean	SD	Median	Minimum	Maximum
Time to notice	88	18.73	9.86	15.96	1.98	50.18
Fixation time	88	8.07	6.34	6.00	0.31	31.81
Dwell time	88	9.29	4.47	9.15	0.98	24.48

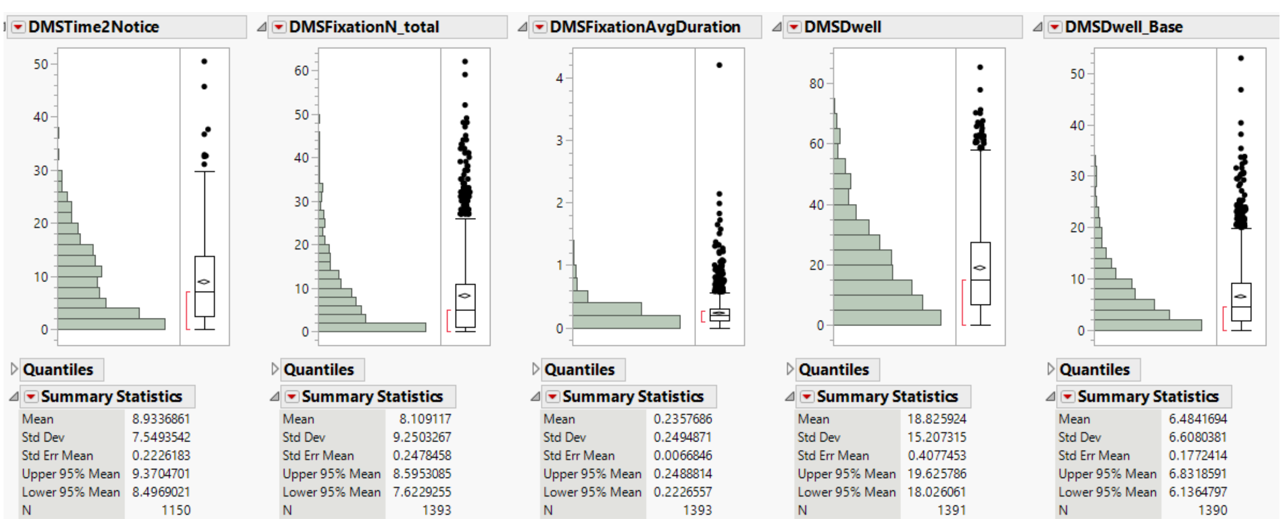


Figure 5-1: Distributions and Descriptive Statistics of Eye-Tracking Parameters

5.3.2 Driver Behavior: Driving Simulator Metrics

- **Longitudinal Velocity:** is the speed of the vehicle moving in a forward direction (ft/sec).
- **Longitudinal Acceleration:** refers to the vehicle's acceleration in a straight line, with a positive value indicating acceleration and a negative value for braking or deceleration (ft/sec^2).
- **Steering Wheel Angle:** the angle between the front of the vehicle and the steered wheel direction (degrees).
- **Lane Position:** the placement of the vehicle in the center, on the right, or on the left of a lane (feet).
- **Time to Collision (TTC):** time to collide with another vehicle if they keep moving in the direction and velocity (seconds).

Summary statistics for behavioral metrics are summarized in **Table 5-3**, where change refers to the difference in driving behavior in Blocks 3-6 compared to Blocks 1-2. **Figure 5-2** demonstrates the distribution of the performance factors across all driving scenarios. Performance factors included longitudinal acceleration, velocity, lateral lane position, steering wheel angle input and minimum time to collision along the roadway sections.

Table 5-3: Summary Statistics for Behavioral Metrics

	N	Mean	SD	Median	Minimum	Maximum
Time to collision change	90	-4.51	1.84	-4.30	-9.18	-1.04
Lane position change	90	-6.61	3.01	-6.30	-14.98	6.82
Speed change	90	7.75	21.65	3.04	-60.07	100.82

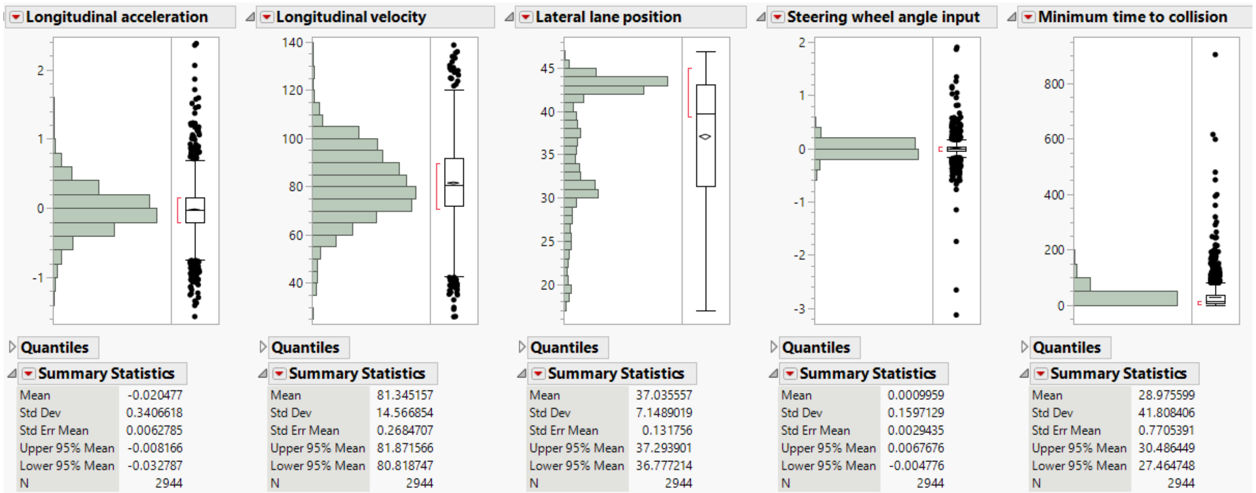


Figure 5-2: Distributions and Descriptive Statistics of Driving Performance Parameters

5.4 Block Data Configuration

The total length of the roadway was set to 2 miles with no curvature on a three 12-foot lanes per direction. The roadway was divided into six (6) blocks 0.25 miles each denoting the speed limit signs, DMS and the added scenario locations to facilitate the data extraction process as shown in **Figure 5-3**. The data were extracted from the driving simulator and then aggregated over two main blocks: Blocks 1-2 and 3-6. Blocks 1-2 denotes the aggregated data for the distance driven by the participants up until the DMS, while Blocks 3-6 denotes the aggregated data for the distance driven after passing the DMS until the end of the scenario. It should be noted that the eye tracking data was available from Blocks 1-2 only, while driving data were collected for both blocks.

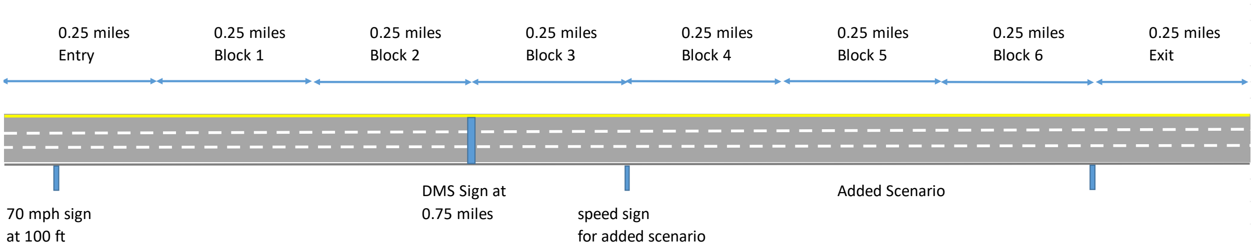


Figure 5-3: Roadway Layout and Blocks Configuration

5.5 Statistical Analysis and Results

5.5.1 Effect of Message Type and Category on Driver Visual Attention

Two mixed-effects multiple regression models were used to examine the degree to which participants' DMS time to notice and dwell time varied based on the message type (creative or traditional) and message category (maneuvering, speeding, visibility, or work zone) with participant number as a random intercept and controlling for the number of words on the message. The findings revealed that the number of words in the message was a significant covariate, with participants noticing signs with more words faster and looking at them longer. In this case, creative signs (M = 6.25, SD = 1.39) had more words than traditional signs (M = 4.88, SD = 1.83). However, this relationship was reversed when examining the dwell time and number fixations. Therefore, a main effect of message type revealed that participants were faster to notice the traditional signs and looked at them longer. Although creative signs were viewed later (M = 9.45, SD = 7.42) than traditional signs (M = 8.39, SD = 7.65), and creative signs were viewed for longer (M = 20.35, SD = 15.79) than traditional signs (M = 17.30, SD = 14.45), the latter effect was reversed in the model when considering the two-way factor interaction between message type and message category. The main effect of sign category was also statistically significant, with participants taking longer to notice the maneuvering signs but also looking at them the shortest time. Notably, the main effects were subsumed by a significant interaction between message type and category. For example, participants tended to look longer toward creative visibility messages compared to the creative maneuvering messages. Whereas participants noticed creative visibility signs faster compared to creative maneuvering signs, when controlling for word number.

In summary, people tend to notice traditional signs faster but look at creative signs longer. Further analysis demonstrated that the latter effect is due, in part, to specific message categories having more words per sign. Therefore, the purpose of the sign had a significant effect on driver's visual attention. For example, creative maneuvering signs took longer to notice compared to traditional visibility signs. **Table 5-4** shows the Time-to-notice (M1) and dwell time (M2) based on message type and category, controlling for the sign's number of words. Default reference categories included creative (sign type) and maneuvering signs (sign category). **Figure 5-4** shows the average time to notice and dwell times by message type and category.

Table 5-4: Time-to-Notice (M1) and Dwell time (M2) Based on Message Type & Category

	Time to notice			Dwell time		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	0.52	0.35 – 0.69	**<0.001**	-0.32	-0.49 – -0.15	**<0.001**
Message: Traditional	-0.61	-0.80 – -0.41	**<0.001**	0.33	0.17 – 0.48	**<0.001**
Category: Speeding	-0.26	-0.44 – -0.07	**0.006**	0.40	0.25 – 0.54	**<0.001**
Category: Visibility	-0.62	-0.81 – -0.44	**<0.001**	0.58	0.43 – 0.73	**<0.001**
Category: Work zone	-0.08	-0.26 – 0.10	0.377	0.03	-0.12 – 0.17	0.713
Sign's number of words	-0.44	-0.50 – -0.38	**<0.001**	0.44	0.40 – 0.49	**<0.001**
Message: Traditional, Category: Speeding	-0.40	-0.66 – -0.13	**0.003**	-0.00	-0.21 – 0.21	0.993
Message: Traditional, Category: Visibility	0.64	0.37 – 0.90	**<0.001**	-0.46	-0.68 – -0.25	**<0.001**
Message: Traditional, Category: Work zone	0.21	-0.05 – 0.47	0.119	-0.28	-0.49 – -0.07	**0.009**
Random Effects						
σ^2	35.39			109.87		
τ_{00}	15.50 Participant			90.10 Participant		
ICC	0.30			0.45		
N	88 Participant			88 Participant		
Observations	1150			1391		
Marginal R^2 / Conditional R^2	0.125 / 0.391			0.140 / 0.527		

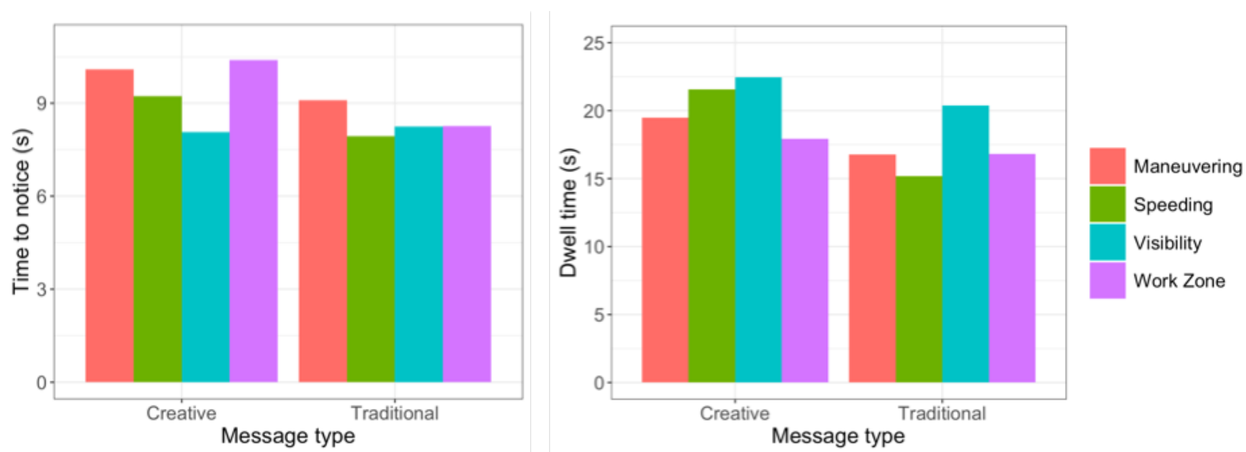


Figure 5-4: DMS time to Notice (left) and Dwell time (right)

Table 5-5 shows the second regression model's significant parameters, main effects, and two-way factor interactions for each of the time to notice (TTN), dwell time and number of fixations while **Figure 5-5** demonstrates the significant interaction between message type and message category expressed in the comparison between Creative Maneuvering messages versus Creative Visibility messages.

Table 5-5: Mixed Model Effects on (a) TTN, (b) Dwell Time, (c) Fixations
(a) Time to Notice

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	9.1509229	0.468845	95.4	19.52	<.0001*
Message Type [Creative]	3.0449477	0.328324	1052	9.27	<.0001*
Message Category [Maneuvering]	3.4690455	0.513531	1056	6.76	<.0001*
Message Category [Speeding]	-5.90607	0.742171	1058	-7.96	<.0001*
Message Category [Visibility]	-2.474768	0.393611	1052	-6.29	<.0001*
Word# [3]	10.761304	1.128822	1057	9.53	<.0001*
Word# [4]	2.7981458	0.53971	1055	5.18	<.0001*
Word# [5]	-4.568417	1.018855	1058	-4.48	<.0001*
Word# [6]	-3.359218	0.713637	1052	-4.71	<.0001*
Word# [7]	-4.974991	0.626265	1054	-7.94	<.0001*
Message Type [Creative]*Message Category [Maneuvering]	-0.304762	0.473409	1054	-0.64	0.5199
Message Type [Creative]*Message Category [Speeding]	2.6361781	0.451835	1054	5.83	<.0001*
Message Type [Creative]*Message Category [Visibility]	-0.099527	0.460041	1056	-0.22	0.8288

(b) Dwell Time

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	18.339763	1.066001	92.31	17.20	<.0001*
Message Type [Creative]	0.1636672	0.536611	1291	0.31	0.7604
Message Category [Maneuvering]	-0.618111	0.806441	1292	-0.77	0.4435
Message Category [Speeding]	1.5221937	1.138086	1292	1.34	0.1813
Message Category [Visibility]	2.1447783	0.646499	1291	3.32	0.0009*
Word# [3]	-3.762836	1.794282	1292	-2.10	0.0362*
Word# [4]	-8.595326	0.857842	1291	-10.02	<.0001*
Word# [5]	-1.912211	1.63527	1293	-1.17	0.2425
Word# [6]	-1.690176	1.136046	1291	-1.49	0.1371
Word# [7]	5.8026008	1.005756	1291	5.77	<.0001*
Message Type [Creative]*Message Category [Maneuvering]	-4.323458	0.774501	1292	-5.58	<.0001*
Message Type [Creative]*Message Category [Speeding]	0.7935728	0.722142	1291	1.10	0.2720
Message Type [Creative]*Message Category [Visibility]	3.1624303	0.721142	1292	4.39	<.0001*

(c) Fixations

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|
Intercept	7.641487	0.684999	91.93	11.16	<.0001*
Message Type [Creative]	1.8371748	0.333113	1293	5.52	<.0001*
Message Category [Maneuvering]	2.9170737	0.500464	1294	5.83	<.0001*
Message Category [Speeding]	-3.08316	0.706554	1294	-4.36	<.0001*
Message Category [Visibility]	-3.169793	0.401341	1293	-7.90	<.0001*
Word# [3]	6.3347674	1.113888	1294	5.69	<.0001*
Word# [4]	-4.235425	0.532429	1293	-7.95	<.0001*
Word# [5]	-5.629119	1.013249	1295	-5.56	<.0001*
Word# [6]	-2.515657	0.705185	1293	-3.57	0.0004*
Word# [7]	-0.162897	0.624281	1293	-0.26	0.7942
Message Type [Creative]*Message Category [Maneuvering]	-3.044631	0.480625	1294	-6.33	<.0001*
Message Type [Creative]*Message Category [Speeding]	2.5103781	0.448306	1293	5.60	<.0001*
Message Type [Creative]*Message Category [Visibility]	2.6481803	0.44769	1294	5.92	<.0001*

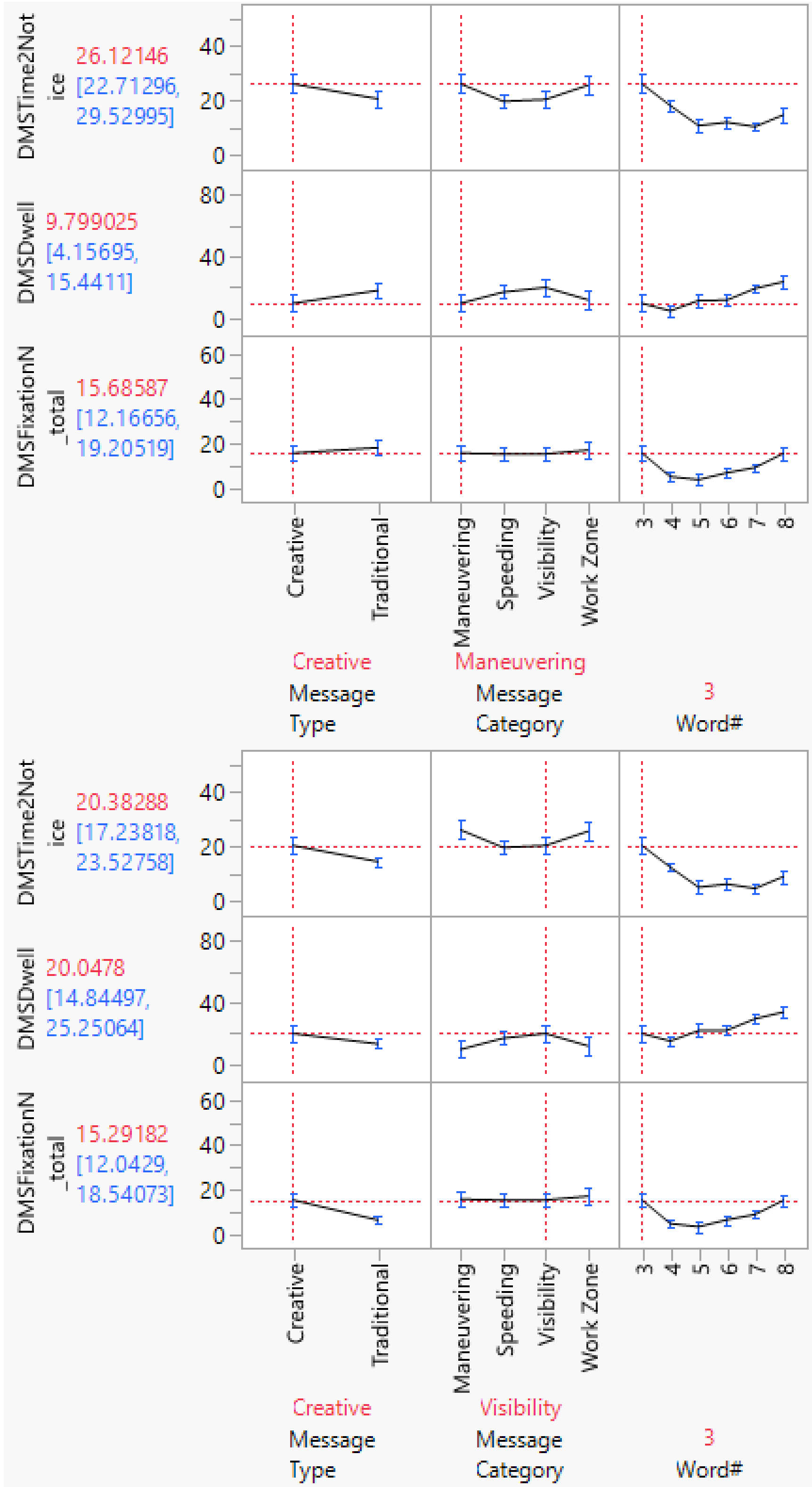


Figure 5-5: Profiler Results for Creative Maneuvering vs. Creative Visibility

5.5.2 Effect of Age and Gender on Driver Visual Attention

Two mixed-effects multiple regression models were used to regress the outcome variables time-to-notice and dwell time on the predictor variables age, gender, and message type, including participant number as a random intercept and controlling for number of words on the sign. Although the main effect of gender was statistically insignificant, the marginally significant main effect of age revealed that older participants took slightly longer to notice the road signs compared to younger participants. A two-way interaction between message type and age revealed that middle-aged participants tended to examine the traditional signs longer compared to young participants examining creative signs. Moreover, a three-way interaction between age, gender, and sign type indicated the middle-aged men spent less time looking at traditional signs, compared to, for example, young women examining creative signs. In short, driver's visual attention toward road signs differs based on background characteristics, such as age and gender, with young women looking at creative signs longer compared to middle-aged men looking at traditional signs. Thus, varying sign types may cater to different audiences.

Table 5-6 shows the Time-to-notice (M1) and dwell time (M2) based on message type, age, and gender, controlling for the sign's number of words. Default reference categories include creative signs (sign type), young drivers (age), and women drivers (gender). **Figure 5-6** shows the average time to notice and dwell time compared to age and gender. **Figure 5-7** shows the profiler for Creative Maneuvering messages for middle-aged females with longer time to notice but shorter dwell and fixation times.

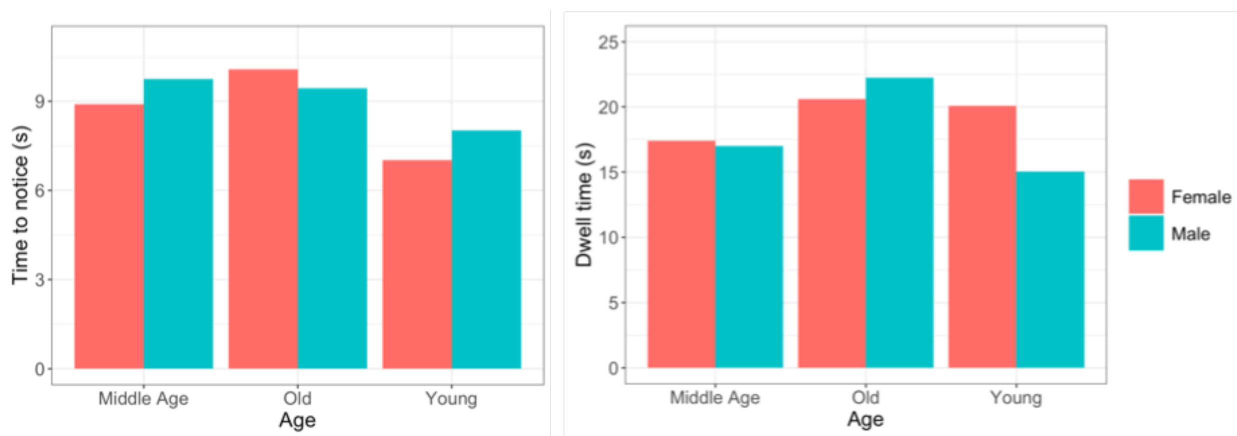


Figure 5-6: DMS time to notice (left) and dwell time (right) based on age and gender.

Table 5-6: Time To Notice (M1) & Dwell Time (M2) By Message Type, Age, and Gender

	Time to notice			Dwell time		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	-0.00	-0.32 – 0.31	**<0.001**	0.09	-0.25 – 0.44	0.084
Message: Traditional	-0.40	-0.64 – -0.16	**0.001**	-0.07	-0.26 – 0.12	0.488
Age: Middle age	0.35	-0.11 – 0.80	0.133	-0.33	-0.82 – 0.16	0.183
Age: Older age	0.38	-0.05 – 0.81	0.079	-0.03	-0.50 – 0.45	0.908
Gender: Male	-0.02	-0.47 – 0.44	0.944	-0.32	-0.81 – 0.18	0.207
Sign's number of words	-0.28	-0.33 – -0.22	**<0.001**	0.32	0.28 – 0.36	**<0.001**
Message: Traditional, Age: Middle age	-0.15	-0.49 – 0.19	0.396	0.36	0.09 – 0.63	**0.008**
Message: Traditional, Age: Older age	0.01	-0.30 – 0.33	0.935	0.16	-0.10 – 0.42	0.219
Message: Traditional, Gender: Male	0.24	-0.11 – 0.59	0.181	0.00	-0.26 – 0.27	0.984
Age: Middle age, Gender, Male	0.04	-0.60 – 0.69	0.894	0.45	-0.25 – 1.15	0.210
Age: Older age, Gender: Male	-0.13	-0.75 – 0.50	0.691	0.46	-0.23 – 1.14	0.190
Message: Traditional, Age: Middle, Gender: Male	-0.09	-0.58 – 0.40	0.729	-0.32	-0.70 – 0.06	0.098
Message: Traditional, Age: Older, Gender: Male	-0.16	-0.62 – 0.30	0.498	-0.06	-0.43 – 0.31	0.749
Random Effects						
σ^2	38.45			119.79		
τ_{00}	15.55 Participant			89.11 Participant		
ICC	0.29			0.43		
N	88 Participant			88 Participant		
Observations	1150			1391		
Marginal R^2 / Conditional R^2	0.093 / 0.354			0.123 / 0.497		

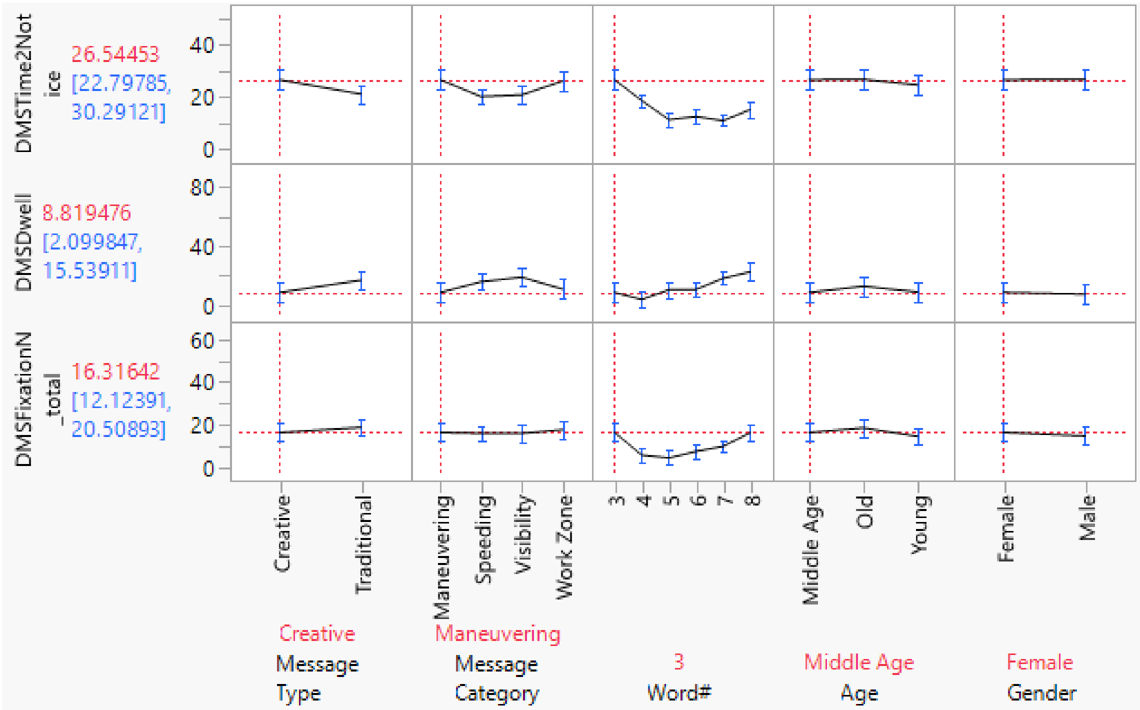


Figure 5-7: Profiler for Creative Maneuvering Messages for Middle-Aged Females

5.5.3 Effect of Time of Day and Traffic Density on Driver Visual Attention

Mixed-effects multiple regression models were used to examine the degree to which participants' message time to notice and dwell time varied based on the message type (creative vs traditional) and driving conditions including time of day (day or night) and traffic density (low or high), with participant number as a random intercept and controlling for the number of words on the message. A significant main effect of time of day demonstrated that participants took longer to notice signs and spent less time looking at signs during night driving, as compared to daytime driving. The main effect of traffic density was also significant, indicating that participants looked longer at signs during low-density conditions, though the time-to-notice was statistically equivalent across traffic densities.

A significant two-way interaction between message type and traffic density revealed that drivers noticed traditional signs in low-density traffic faster and looked at them for shorter durations, as compared to creative signs in high-density traffic. The two-way interaction between time-of-day and traffic density was also significant, with drivers noticing signs faster and looking for shorter durations during the night and low-density traffic. Taken together, nighttime, and high-density traffic conditions altered gaze behavior, with drivers requiring more time to notice and spending less time looking at signs. This effect was modulated by sign type, such that drivers noticed traditional signs faster but spend less time looking at them.

Table 5-7 shows the Time-to-notice (M1) and dwell time (M2) based on message type, time of day, and traffic density, controlling for the sign's number of words. Default reference categories include creative signs (sign type), daytime driving (time of day), and low-density traffic (traffic density). **Figure 5-8** summarizes the mean values for TTN and dwell times for TOD and traffic density. **Figure 5-9** shows the profiler for Creative Maneuvering messages during off peak daytime with longer time to notice and fixation time, but shorter dwell time compared to the traditional messages.

Table 5-7: Change in TTN (M1), Dwell Time (M2) by Message Type, TOD & Traffic Density

	Time to notice			Dwell time		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	0.15	-0.03 – 0.32	**<0.001**	0.19	0.02 – 0.36	**<0.001**
Message: Traditional	-0.26	-0.41 – -0.12	**<0.001**	-0.13	-0.25 – -0.01	**0.035**
Time of day: Night	0.29	0.00 – 0.59	**0.048**	-0.29	-0.51 – -0.07	**0.011**
Traffic density: Low	0.12	-0.10 – 0.33	0.284	0.31	0.14 – 0.49	**<0.001**
Sign's number of words	-0.27	-0.38 – -0.15	**<0.001**	0.22	0.13 – 0.30	**<0.001**
Message: Traditional, Time of day: Night	0.15	-0.16 – 0.47	0.336	0.19	-0.06 – 0.43	0.135
Message: Traditional, Traffic density: Low	-0.60	-1.04 – -0.15	**0.008**	-0.10	-0.44 – 0.25	0.582
Time of day: Night, Traffic density: Low	-0.36	-0.67 – -0.06	**0.019**	-0.49	-0.73 – -0.25	**<0.001**
Message: Traditional, Time of day: Night, Traffic density: Low	0.35	-0.16 – 0.87	0.177	0.13	-0.27 – 0.53	0.531
Random Effects						
σ^2	36.79			110.52		
τ_{00}	15.69 Participant			90.03 Participant		
ICC	0.30			0.45		
N	88 Participant			88 Participant		
Observations	1150			1391		
Marginal R^2 / Conditional R^2	0.101 / 0.369			0.137 / 0.525		

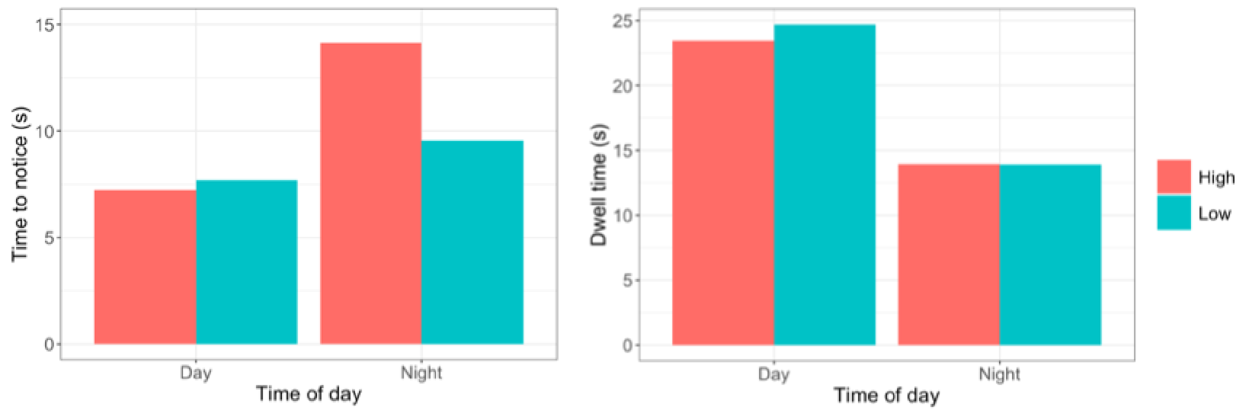


Figure 5-8: DMS TTN (left) & Dwell Time (right) vs. TOD & Traffic Density

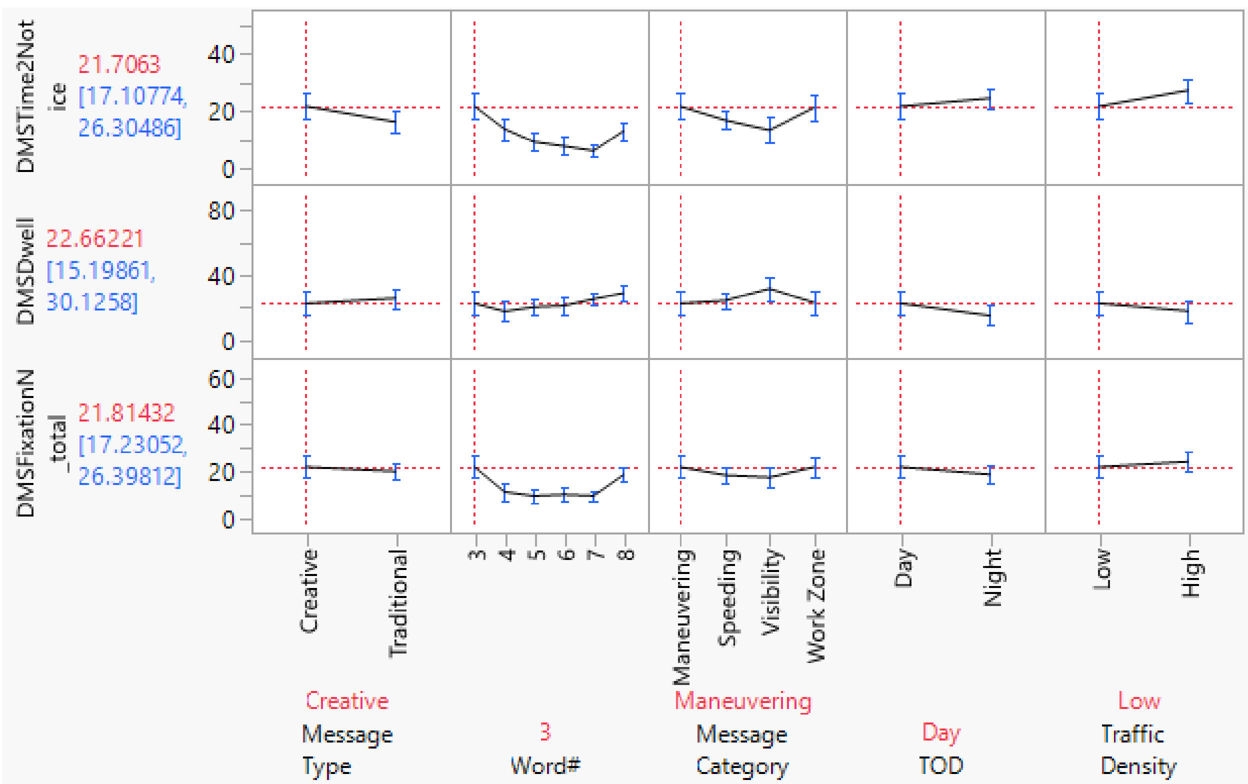


Figure 5-9: Profiler for Creative Maneuvering Messages during Off-Peak Daytime

5.5.4 Effect of Message type and Category on Driver Behavior

Due to the present focus on how messages alter driver's behaviors, we modeled the differences in driver's behaviors after sign viewing compared to before and during sign viewing (i.e., average from blocks 3-6 minus average from blocks 1-2). We examined driver's behavioral changes following road sign viewing using a series of mixed-effects multiple regression models with change in time-to-collision, lane position, and speed (longitudinal velocity) as outcome variables. Message type and category were included as predictor variables, with participant number as a random intercept and number of words in the message as a control variable.

Using this approach, a significant main effect of sign type indicated that driver's time-to-collision was increased more in the presence of creative versus traditional signs which indicated safer conditions. In addition, greater decreases in lane position change occurred following creative signs compared to traditional signs. Notably, number of words per sign was a significant covariate, such that messages with more words were associated with greater decreases in time-to-collision, lane position, and speed. The significant main effect of sign category further demonstrated that maneuvering signs were significantly associated with increased time-to-collision compared to visibility signs. In addition, maneuvering signs resulted in more reduction in lane position change and reduced speed compared to visibility signs and speeding signs. The main effects were subsumed by a two-way interaction between sign type and category, demonstrating that creative maneuvering signs were associated with greater time-to-collision and reduced speed compared to traditional speeding signs. However, creative maneuvering signs were associated with reduced time-to-collision and greater speed compared to traditional visibility messages. Lastly, drivers had less lane position shifts and lower speed with creative maneuvering signs compared to traditional work zone signs.

Overall, creative signs lead to a greater increase in time-to-collision with less lane position shifts compared to traditional signs. The relative effectiveness of creative versus traditional signs depends, in part, on the sign category. Overall, the findings suggest complicated changes in combinations of driving behavior based on sign type and category, for example, where the relationship between time-to-collision, lane position, and speed differs based on features of the sign. **Table 5-8** shows the changes in time-to-collision (M1), lane position (M2), and speed (M3) based on message type and category, controlling for the sign's number of words. Default reference categories include creative (sign type) and maneuvering signs (sign category).

Table 5-8: Change in TTC (M1), Lane Position (M2), Speed (M3) by MT & Category

	Time to collision change			Lane position change			Speed change		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	0.33	0.16 – 0.49	**<0.001**	0.54	0.39 – 0.70	0.695	-0.21	-0.37 – -0.06	**<0.001**
Message: Traditional	-0.37	-0.57 – -0.17	**<0.001**	-0.40	-0.60 – -0.21	**<0.001**	0.06	-0.15 – 0.27	0.570
Category: Speeding	-0.10	-0.29 – 0.09	0.303	-0.68	-0.87 – -0.49	**<0.001**	0.47	0.27 – 0.67	**<0.001**
Category: Visibility	-0.47	-0.66 – -0.27	**<0.001**	-0.91	-1.10 – -0.71	**<0.001**	0.56	0.36 – 0.76	**<0.001**
Category: Work zone	-0.07	-0.26 – 0.12	0.443	-0.07	-0.26 – 0.12	0.484	-0.02	-0.22 – 0.17	0.816
Sign's number of words	-0.11	-0.17 – -0.05	**0.001**	-0.11	-0.17 – -0.05	**<0.001**	-0.07	-0.13 – -0.00	**0.038**
Message: Traditional, Category: Speeding	-0.30	-0.57 – -0.03	**0.028**	-0.05	-0.32 – 0.22	0.716	-0.57	-0.84 – -0.29	**<0.001**
Message: Traditional, Category: Visibility	0.43	0.15 – 0.71	**0.002**	0.96	0.68 – 1.23	**<0.001**	-0.48	-0.76 – -0.19	**0.001**
Message: Traditional, Category: Work zone	0.04	-0.23 – 0.31	0.758	-0.33	-0.60 – -0.06	**0.017**	0.50	0.22 – 0.78	**0.001**
Random Effects									
σ^2	2121.23			23.36			77.79		
τ_{00}	336.30 $_{Participant}$			1.93 $_{Participant}$			4.18 $_{Participant}$		
ICC	0.14			0.08			0.05		
N	90 $_{Participant}$			90 $_{Participant}$			90 $_{Participant}$		
Observations	1440			1440			1440		
Marginal R^2 / Conditional R^2	0.039 / 0.170			0.116 / 0.183			0.060 / 0.108		

Figure 5-10 shows the Change in time-to-collision (top left), lane position (top right), and speed (bottom left) based on message type and category, where change refers to the difference in driving behavior after sign viewing compared to before and during sign viewing.

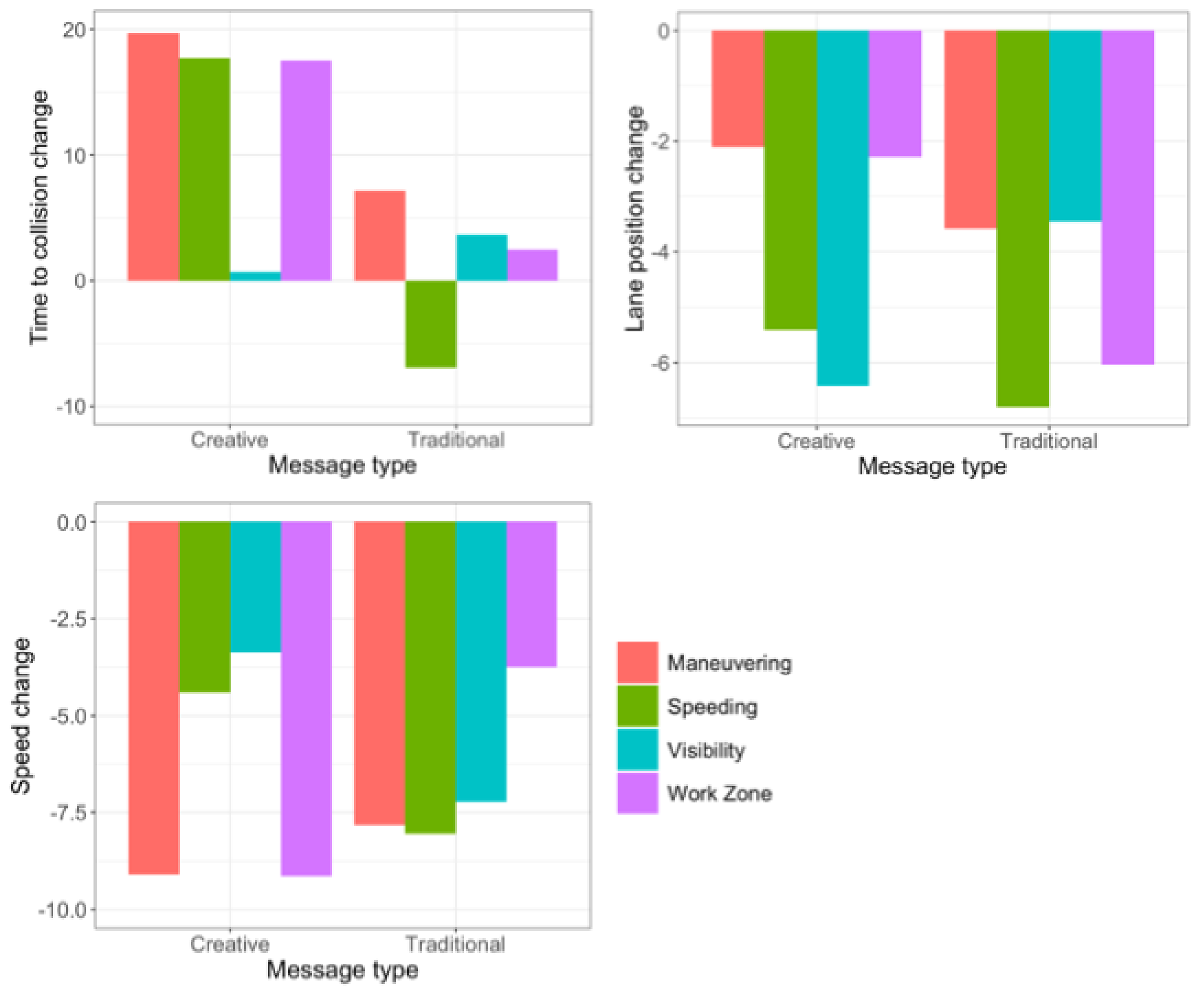


Figure 5-10: Change in TTC, Lane Position, and Speed Based on Message Type and Category

5.5.5 Effect of Age and Gender on Driver Behavior

Next, we examined the differences in driver's behaviors (i.e., time-to-collision, lane position, and speed) using mixed-effects multiple regression models with message type, age, and gender as predictor variables, participant number as a random intercept, and number of words in the message as a control variable. The main effect of age was statistically significant, with middle-age and older drivers having a greater time-to-collision than younger drivers. A main effect of gender indicated that female drivers had less changes in lane position following the road signs, as compared to male drivers. In addition, the significant interaction between sign type and age showed that older participants had reduced time-to-collision in the presence of traditional signs, as compared to young people viewing creative signs. A significant interaction between sign type and gender further revealed that male drivers exhibited greater lane change positions following traditional signs, compared to women viewing creative signs.

In summary, although many of the behavioral changes following sign viewing were consistent across demographic groups, age and gender interacted with sign type in some circumstances. Whereas older drivers tend to have greater time-to-collision than younger drivers, older drivers viewing traditional signs had reduced time-to-collision compared to younger drivers viewing creative signs. Thus, similar to the visual attention results, behaviors in response to road signs differ to some extent based on background characteristics.

Table 5-9 shows Changes in time-to-collision (M1), lane position (M2), and speed (M3) based on message type, age, and gender, controlling for the sign's number of words. Default reference categories include creative signs (sign type), young drivers (age), and women drivers (gender).

Table 5-9: TTC (M1), Lane Position (M2) & Speed (M3) vs. Message Type, Age & Gender

	Time to collision change			Lane position change			Speed change		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	-0.01	-0.26 – 0.23	0.190	0.09	-0.12 – 0.29	**<0.001**	0.09	-0.12 – 0.30	**0.001**
Message: Traditional	-0.17	-0.41 – 0.07	0.165	-0.45	-0.70 – -0.21	**<0.001**	-0.13	-0.38 – 0.12	0.307
Age: Middle age	0.36	0.02 – 0.70	**0.040**	0.03	-0.26 – 0.32	0.836	-0.16	-0.45 – 0.14	0.291
Age: Older age	0.43	0.09 – 0.77	**0.013**	0.25	-0.03 – 0.54	0.084	-0.17	-0.46 – 0.12	0.249
Gender: Male	-0.13	-0.48 – 0.22	0.451	-0.26	-0.55 – 0.04	0.091	0.13	-0.17 – 0.43	0.389
Sign's number of words	-0.02	-0.07 – 0.03	0.442	0.04	-0.02 – 0.09	0.191	-0.05	-0.10 – 0.01	0.086
Message: Traditional, Age: Middle age	-0.15	-0.48 – 0.18	0.371	0.33	-0.02 – 0.67	0.061	0.16	-0.19 – 0.51	0.371
Message: Traditional, Age: Older age	-0.35	-0.68 – -0.03	**0.034**	0.21	-0.13 – 0.55	0.222	0.11	-0.23 – 0.46	0.526
Message: Traditional, Gender: Male	0.08	-0.26 – 0.41	0.658	0.41	0.06 – 0.76	**0.022**	-0.21	-0.57 – 0.15	0.245
Age: Middle age, Gender, Male	-0.13	-0.62 – 0.36	0.591	0.19	-0.22 – 0.61	0.358	-0.04	-0.45 – 0.38	0.866
Age: Older age, Gender: Male	-0.21	-0.69 – 0.28	0.400	-0.11	-0.52 – 0.30	0.589	-0.03	-0.45 – 0.38	0.872
Message: Traditional, Age: Middle, Gender: Male	-0.01	-0.48 – 0.47	0.977	-0.29	-0.78 – 0.20	0.248	0.18	-0.32 – 0.68	0.475
Message: Traditional, Age: Older, Gender: Male	0.26	-0.21 – 0.73	0.273	-0.15	-0.64 – 0.34	0.549	0.31	-0.18 – 0.81	0.214
Random Effects									
σ^2	2170.40			26.42			82.74		
τ_{00}	312.43 Participant			1.38 Participant			4.12 Participant		
ICC	0.13			0.05			0.05		
N	90 Participant			90 Participant			90 Participant		
Observations	1440			1440			1440		
Marginal R^2 / Conditional R^2	0.038 / 0.159			0.033 / 0.081			0.010 / 0.057		

Figure 5-11 shows the Change in time-to-collision (top left), lane position (top right), and speed (bottom left) based on age and gender, where change refers to the difference in driving behavior after sign viewing compared to before and during sign viewing.

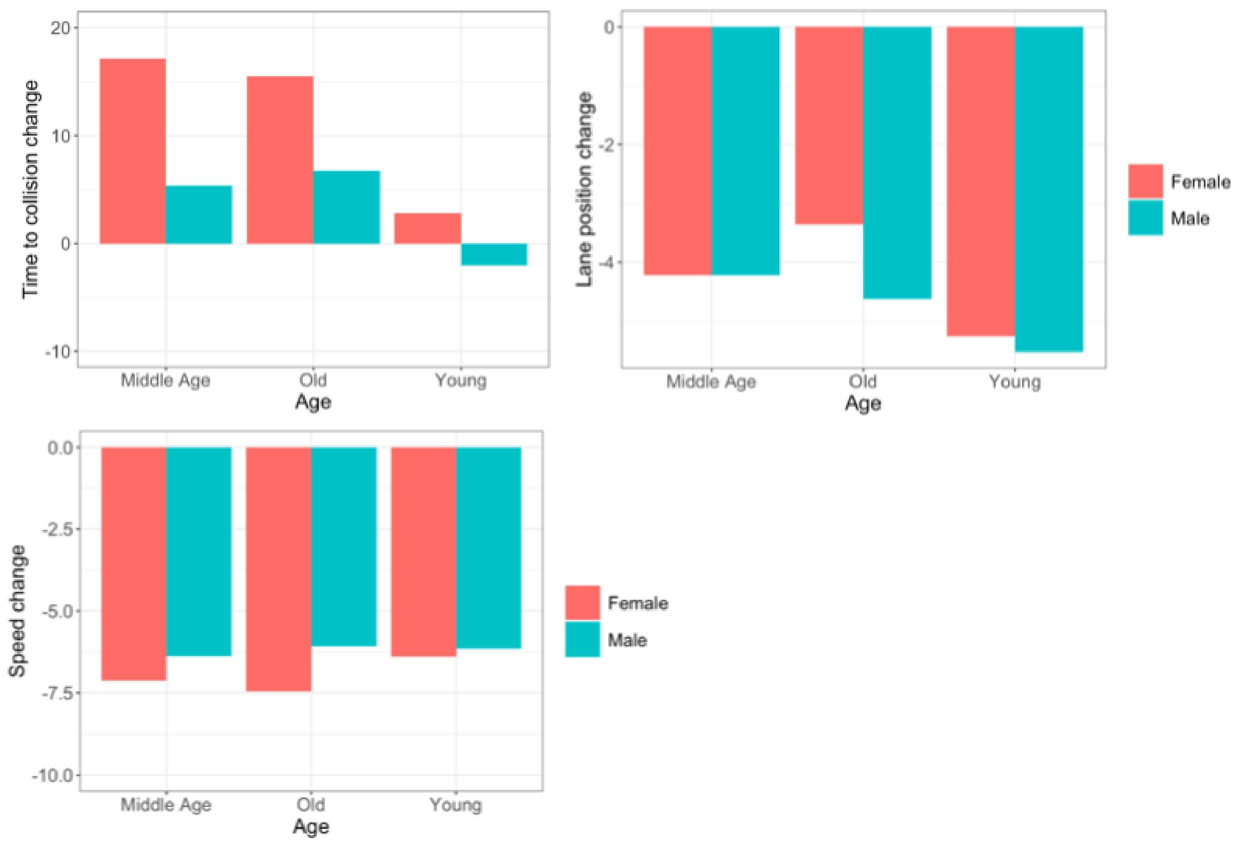


Figure 5-11: Change in TTC, Lane Position, and Speed Based on Age and Gender

5.5.3 Effect of Time of Day and Traffic Density on Driver behavior

Lastly, differences in driver's behaviors based on driving conditions were investigated using mixed-effects multiple regression models with message type, time of day, and traffic density as predictor variables, participant number as a random intercept, and number of words in the message as a control variable. Examining the behavioral averages based on message type, participants demonstrate a significantly decreased time-to-collision, lane changes, and speed with traditional versus creative signs, with time-to-collision showing the greatest differences based on message type. However, suppression effects within the model altered the direction and strength of the relationship between speed change and sign type.

A significant main effect of time of day indicated that drivers had reduced time-to-collision and less changes in lane position during nighttime driving. In addition, the main effect of traffic density demonstrated that low-density traffic conditions resulted in less changes in lane position. Moreover, the significant interaction between sign type and time of day revealed that drivers had greater time-to-collision, less lane position changes, and lessened speed during nighttime conditions with traditional signs, as compared to daytime driving with creative signs. An additional interaction between sign type and traffic density showed reduced time-to-collision and speed during low-density traffic with traditional signs, compared to high-density traffic with creative signs. The two-way interaction between time of day and traffic density demonstrated that low-density nighttime driving resulted in reduced time-to-collision and greater lane changes than high-density daytime driving. The main effects and two-way interactions were subsumed by a significant three-way interaction between sign type, time of day, and traffic density, which indicated significantly reduced time-to-collision and greater lane changes following traditional sign viewing in low-density nighttime driving, compared to creative sign viewing in high-density daytime driving. Building on prior behavioral models that highlight complicated changes in combinations of driving behavior based on sign type, the present findings suggest that combinations of driving behaviors vary not only based on sign type but also in tandem with driving conditions.

Table 5-10 shows the Changes in time-to-collision (M1), lane position (M2), and speed (M3) based on message type, time of day, and traffic density, controlling for the sign's number of words. Default reference categories include creative signs (sign type), daytime driving (time of day), and low-density traffic (traffic density).

Table 5-10: TTC (M1), Lane Position (M2) & Speed (M3) vs. MT, TOD & Traffic Density

	Time to collision change			Lane position change			Speed change		
Predictors	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*	*std. Beta*	*standardized CI*	*p*
Intercept	0.29	0.13 – 0.45	**<0.001**	0.02	-0.13 – 0.17	**<0.001**	-0.11	-0.26 – 0.04	0.760
Message: Traditional	-0.15	-0.30 – 0.00	0.053	0.11	-0.05 – 0.26	0.173	0.71	0.56 – 0.86	**<0.001**
Time of day: Night	-0.60	-0.89 – -0.31	**<0.001**	-0.35	-0.63 – -0.06	**0.017**	0.21	-0.08 – 0.49	0.151
Traffic density: Low	-0.17	-0.40 – 0.05	0.132	-0.50	-0.72 – -0.28	**<0.001**	0.10	-0.12 – 0.32	0.386
Sign's number of words	-0.20	-0.31 – -0.09	**0.001**	0.02	-0.09 – 0.13	0.730	-0.28	-0.40 – -0.17	**<0.001**
Message: Traditional, Time of day: Night	0.35	0.03 – 0.66	**0.030**	0.82	0.52 – 1.13	**<0.001**	-1.23	-1.54 – -0.92	**<0.001**
Message: Traditional, Traffic density: Low	-0.44	-0.88 – -0.00	**0.050**	0.21	-0.22 – 0.65	0.340	-0.93	-1.36 – -0.49	**<0.001**
Time of day: Night, Traffic density: Low	0.78	0.47 – 1.09	**<0.001**	1.28	0.97 – 1.58	**<0.001**	0.22	-0.09 – 0.52	0.168
Message: Traditional, Time of day: Night, Traffic density: Low	-0.54	-1.05 – -0.02	**0.041**	-2.08	-2.59 – -1.57	**<0.001**	0.34	-0.17 – 0.84	0.193
Random Effects									
σ^2	2090.49			22.84			69.69		
τ_{00}	338.22 Participant			1.96 Participant			4.69 Participant		
ICC	0.14			0.08			0.06		
N	90 Participant			90 Participant			90 Participant		
Observations	1440			1440			1440		
Marginal R^2 / Conditional R^2	0.050 / 0.182			0.133 / 0.201			0.147 / 0.201		

Figure 5-12 shows the Change in time-to-collision (top left), lane position (top right), and speed (bottom left) based on time of day and traffic density, where change refers to the difference in driving behavior after sign viewing compared to before and during sign viewing.

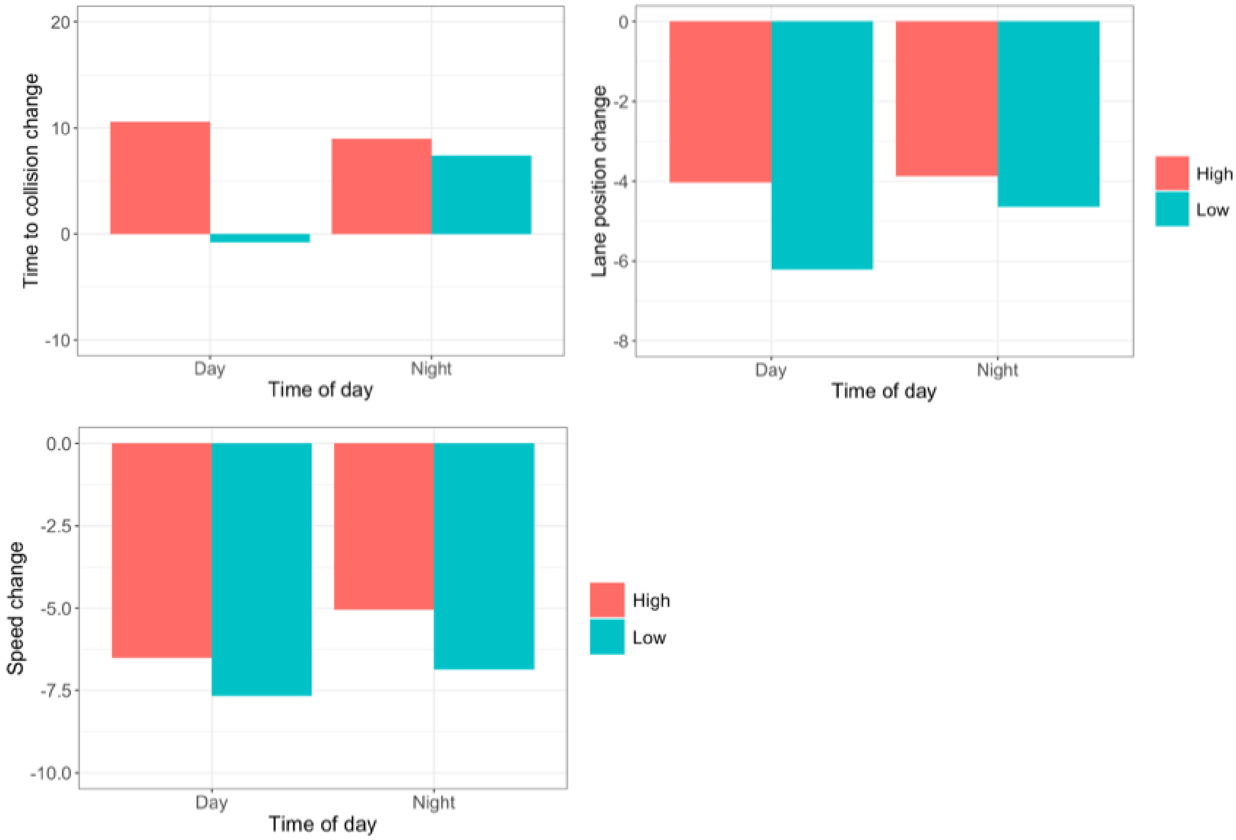


Figure 5-12: Change in TTC, Lane Position, and Speed for Time of Day and Traffic Density

5.6 Survey Results and Analysis

5.6.1 Assessment of Workload (NASA-TLX)

A 3X2X6 mixed-factorial design involving Age group (young, middle-aged, and older) and gender (male and female) as between-subjects variables and NASA-TLX scores for each of the six workload dimensions (mental demand, physical demand, temporal demand, effort, frustration, and performance) as within-subjects (repeated measures) variables was used. The dependent variables were the scores each of the six Task Load Index dimensions. Results showed a significant main effect of workload category on participants' simulation scores $F(5,435) = 52.149$, $p<.001$, $\eta p2=.38$. The effect of workload category on participants' workload is depicted in **Figure 5-13**.

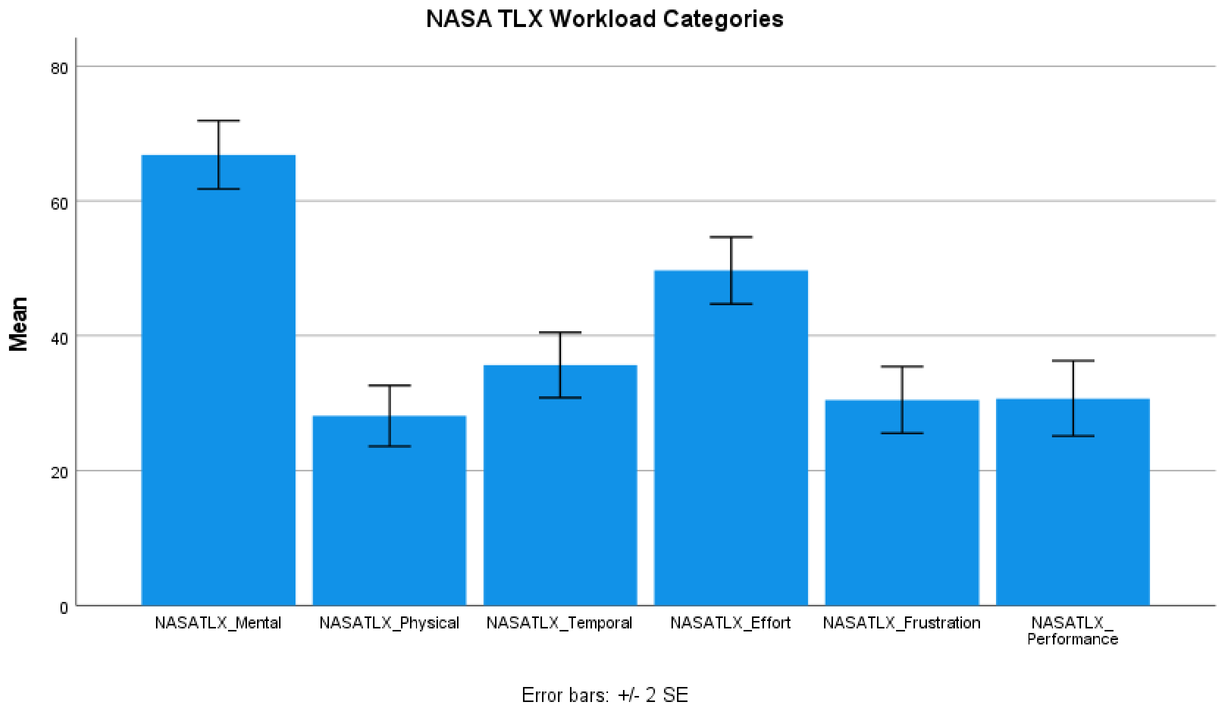


Figure 5-13: Effect of workload category on participants

The results of post hoc comparisons among each of these 6 workload categories are presented in **Table 5-11**.

Table 5-11: Pairwise Comparisons between Participants Workload

Pairwise Comparisons					
Measure:	Workload Categories **Green Depicts Significant differences**				
Sickness Category			Mean Difference (I-J)	Std. Error	Sig.[b]
1	Young	MiddleAge	-10.042	6.059	0.101
		Old	-16.615*	6.059	0.007
	MiddleAge	Young	10.042	6.059	0.101
		Old	-6.573	6.059	0.281
	Old	Young	16.615*	6.059	0.007

		MiddleAge	6.573	6.059	0.281
2	Young	MiddleAge	-11.927*	5.424	0.031
		Old	-0.031	5.424	0.995
	MiddleAge	Young	11.927*	5.424	0.031
		Old	11.896*	5.424	0.031
	Old	Young	0.031	5.424	0.995
		MiddleAge	-11.896*	5.424	0.031
3	Young	MiddleAge	-10.625	5.746	0.068
		Old	-1.104	5.746	0.848
	MiddleAge	Young	10.625	5.746	0.068
		Old	9.521	5.746	0.101
	Old	Young	1.104	5.746	0.848
		MiddleAge	-9.521	5.746	0.101
4	Young	MiddleAge	-6.833	5.970	0.256
		Old	-9.646	5.970	0.110
	MiddleAge	Young	6.833	5.970	0.256
		Old	-2.813	5.970	0.639
	Old	Young	9.646	5.970	0.110
		MiddleAge	2.813	5.970	0.639
5	Young	MiddleAge	-9.365	6.069	0.126
		Old	2.167	6.069	0.722
	MiddleAge	Young	9.365	6.069	0.126
		Old	11.531	6.069	0.061
	Old	Young	-2.167	6.069	0.722
		MiddleAge	-11.531	6.069	0.061
6	Young	MiddleAge	0.250	6.809	0.971
		Old	8.427	6.809	0.219

	MiddleAge	Young	-0.250	6.809	0.971
		Old	8.177	6.809	0.233
	Old	Young	-8.427	6.809	0.219
		MiddleAge	-8.177	6.809	0.233

Additionally, there was a significant interaction of age group by workload category on participants' simulation scores (5,435) = 2.035, $p<.05$, $\eta p2=.38$. The results of tests of simple effects and their significance are presented in **Table 5-12**.

Table 5-12: Effect of Age on Workload Categories

Pairwise Comparisons					
Measure:	Interaction of Age and Workload Categories **Green Depicts Significant differences**				
Age Category			Mean Difference (I-J)	Std. Error	Sig.[b]
Young	1	2	33.854*	5.117	<0.001
		3	26.323*	4.678	<0.001
		4	13.677*	4.090	0.001
		5	29.917*	5.387	<0.001
		6	24.385*	6.566	<0.001
	2	1	-33.854*	5.117	<0.001
		3	-7.531	3.907	0.057
		4	-20.177*	5.081	<0.001
		5	-3.938	4.852	0.419
		6	-9.469*	4.607	0.043
	3	1	-26.323*	4.678	<0.001
		2	7.531	3.907	0.057
		4	-12.646*	5.288	0.019

		5	3.594	4.402	0.416
		6	-1.938	5.679	0.734
	4	1	-13.677*	4.090	0.001
		2	20.177*	5.081	<0.001
		3	12.646*	5.288	0.019
		5	16.240*	4.998	0.002
		6	10.708	6.288	0.092
	5	1	-29.917*	5.387	<0.001
		2	3.938	4.852	0.419
		3	-3.594	4.402	0.416
		4	-16.240*	4.998	0.002
		6	-5.531	5.660	0.331
	6	1	-24.385*	6.566	<0.001
		2	9.469*	4.607	0.043
		3	1.938	5.679	0.734
		4	-10.708	6.288	0.092
		5	5.531	5.660	0.331
MiddleAge	1	2	31.969*	5.117	<0.001
		3	25.740*	4.678	<0.001
		4	16.885*	4.090	<0.001
		5	30.594*	5.387	<0.001
		6	34.677*	6.566	<0.001
	2	1	-31.969*	5.117	<0.001
		3	-6.229	3.907	0.114
		4	-15.083*	5.081	0.004
		5	-1.375	4.852	0.778
		6	2.708	4.607	0.558

	3	1	-25.740*	4.678	<0.001
		2	6.229	3.907	0.114
		4	-8.854	5.288	0.098
		5	4.854	4.402	0.273
		6	8.937	5.679	0.119
	4	1	-16.885*	4.090	<0.001
		2	15.083*	5.081	0.004
		3	8.854	5.288	0.098
		5	13.708*	4.998	0.007
		6	17.792*	6.288	0.006
	5	1	-30.594*	5.387	<0.001
		2	1.375	4.852	0.778
		3	-4.854	4.402	0.273
		4	-13.708*	4.998	0.007
		6	4.083	5.660	0.473
	6	1	-34.677*	6.566	<0.001
		2	-2.708	4.607	0.558
		3	-8.937	5.679	0.119
		4	-17.792*	6.288	0.006
		5	-4.083	5.660	0.473
Old	1	2	50.438*	5.117	<0.001
		3	41.833*	4.678	<0.001
		4	20.646*	4.090	<0.001
		5	48.698*	5.387	<0.001
		6	49.427*	6.566	<0.001
	2	1	-50.438*	5.117	<0.001
		3	-8.604*	3.907	0.030

		4	-29.792*	5.081	<0.001
		5	-1.740	4.852	0.721
		6	-1.010	4.607	0.827
	3	1	-41.833*	4.678	<0.001
		2	8.604*	3.907	0.030
		4	-21.188*	5.288	<0.001
		5	6.865	4.402	0.123
		6	7.594	5.679	0.185
	4	1	-20.646*	4.090	<0.001
		2	29.792*	5.081	<0.001
		3	21.188*	5.288	<0.001
		5	28.052*	4.998	<0.001
		6	28.781*	6.288	<0.001
	5	1	-48.698*	5.387	<0.001
		2	1.740	4.852	0.721
		3	-6.865	4.402	0.123
		4	-28.052*	4.998	<0.001
		6	0.729	5.660	0.898
	6	1	-49.427*	6.566	<0.001
		2	1.010	4.607	0.827
		3	-7.594	5.679	0.185
		4	-28.781*	6.288	<0.001
		5	-0.729	5.660	0.898

The effect of age group and workload categories is depicted in **Figure 5-14**.

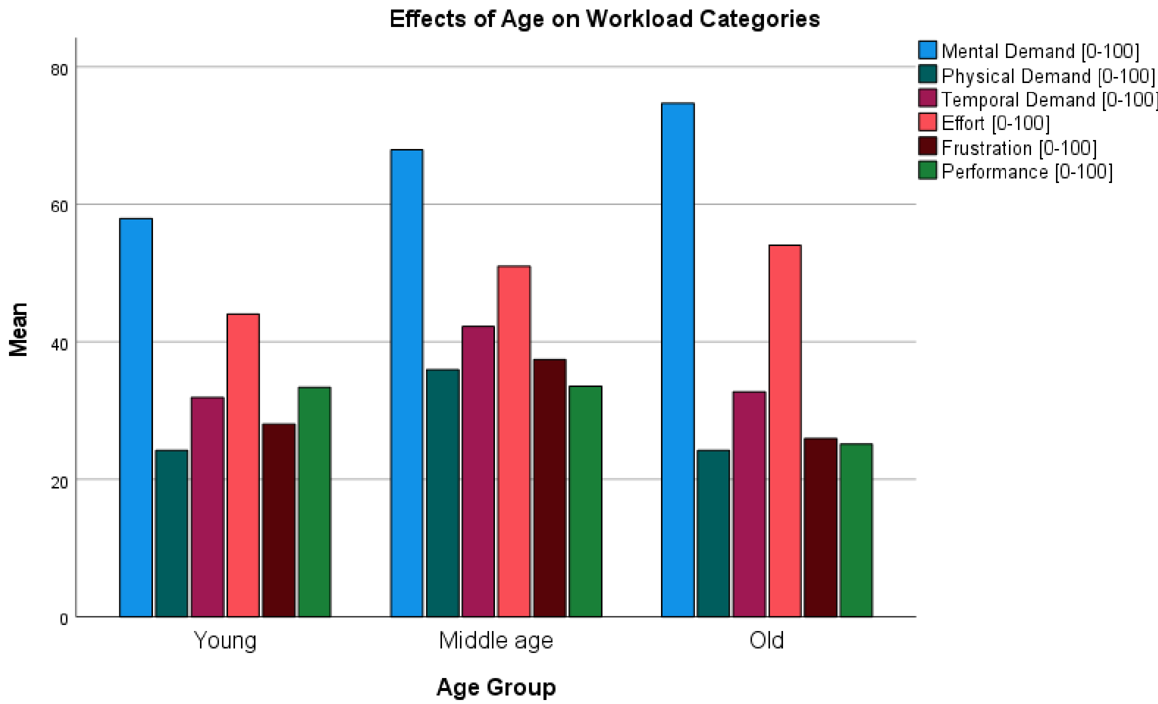


Figure 5-14: The Effects of Age Group and Workload Categories

5.6.2 Assessment of Simulation Sickness Symptoms (SSQ)

A 3X2X3 mixed-factorial design involving Age group (young, Middle-aged, and old) and gender (male and female) as between-subjects variables and Sickness type (Nausea, oculomotor, and disorientation) as within-subjects (repeated measures) variables was used. The dependent variables were the scores on the Simulation Sickness Questionnaire (SSQ) for each of the three sickness types. The results showed significant effects of sickness type on the simulation sickness scores F (2, 174 = 5.918, p<.01, Post hoc comparisons indicated that participants reported higher sickness scores of oculomotors (Mean=7.096; SE= 1.30) than Nausea scores (Mean= 2.789; SE= .76), p<.05. However, there were no significant difference between Nausea and disorientation scores (p>.05), as well as between disorientation scores and oculomotor scores (p>.05).

In addition, there was a significant interaction effect between gender and sickness type scores F (2, 174) = 4.278, p<.05. Tests of simple effects indicated that for the male participants, there was a significant difference between their nausea scores and oculomotor scores (MD=4.183; SE=1.06; p<.01), as well as disorientation scores (MD=5.241; SE=1.062; p<.01). However, there was no significant difference between the oculomotor and disorientations scores (p>.05). Similarly, for the female participants, there was a significant difference between their nausea sores and oculomotor scores (MD=4.426; SE=1.06; p<.001), as well as disorientation scores (MD=5.404; SE=1.062; p<.01). However, there was no significant difference e between the female oculomotor and disorientations scores (p>.05). Finally, none of the other simple effects were significant (p<0.05). This interaction effect is depicted in **Figure 5-15**.

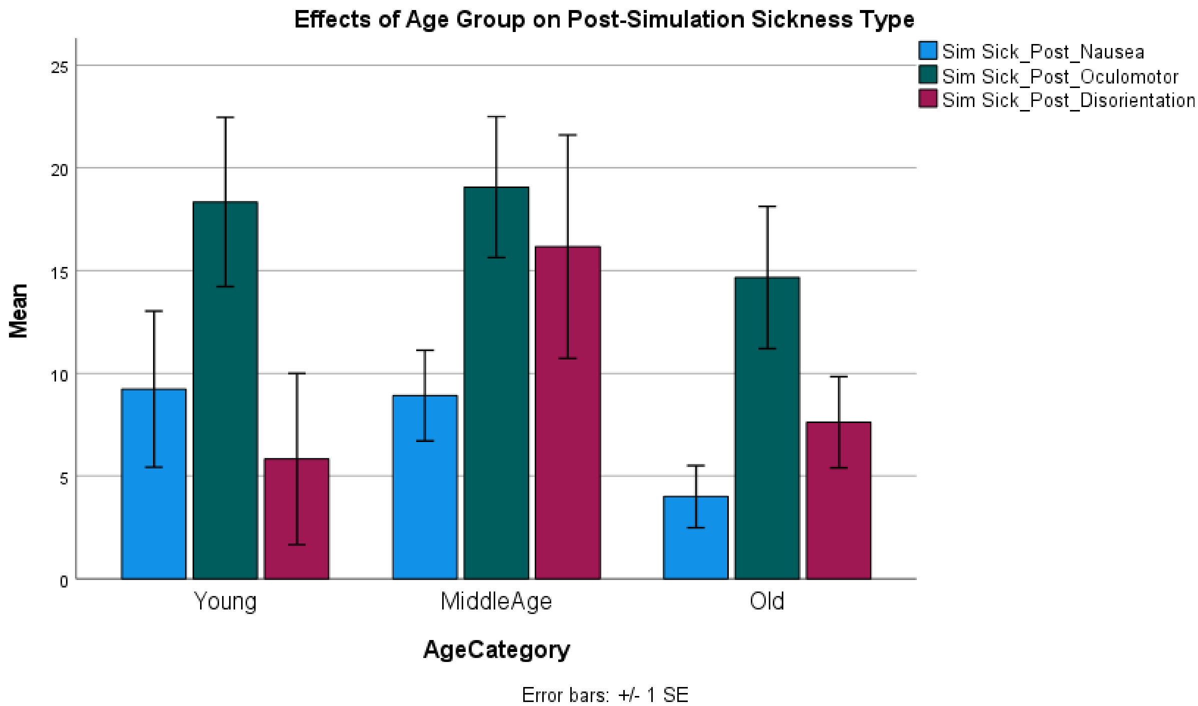


Figure 5-15: Effect of Age Group on Sickness Type

The following **Figures 5-16** to **Figures 5-22** show the effects of NASA TLX workload categories, simulation sickness (Pre- and Post), as well as the effect of gender on the aforementioned parameters.

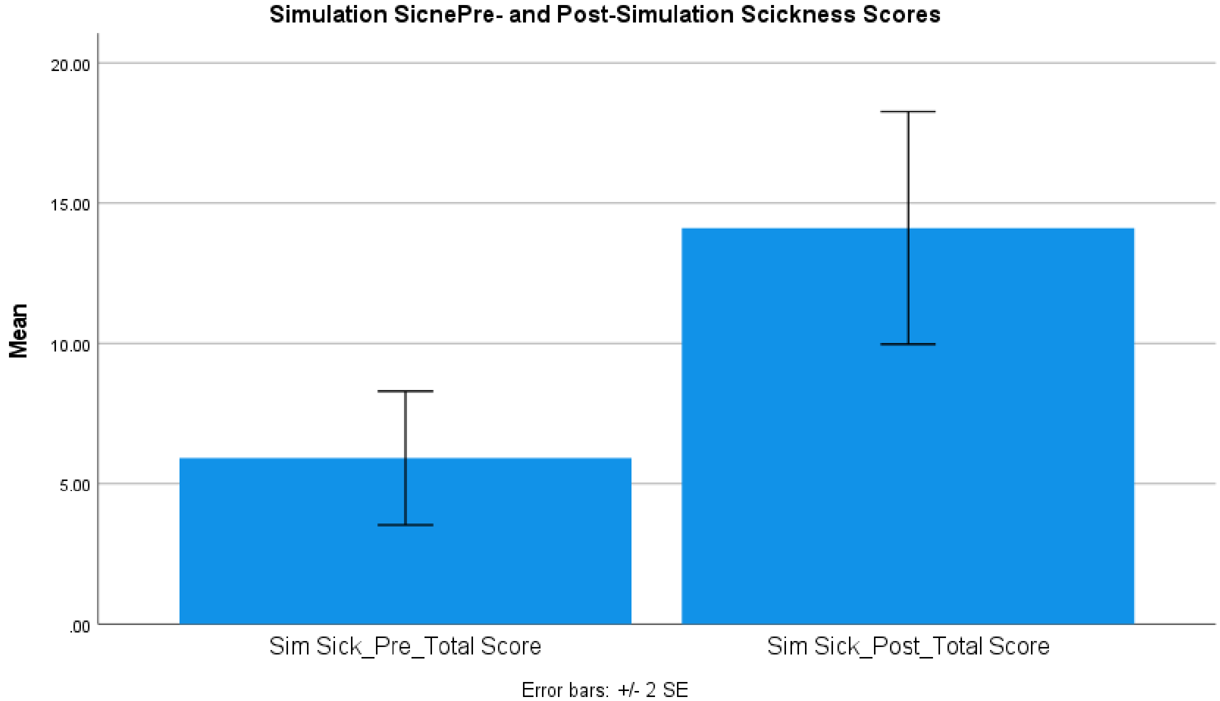


Figure 5-16: Simulation Sickness Pre- and Post-Experiment

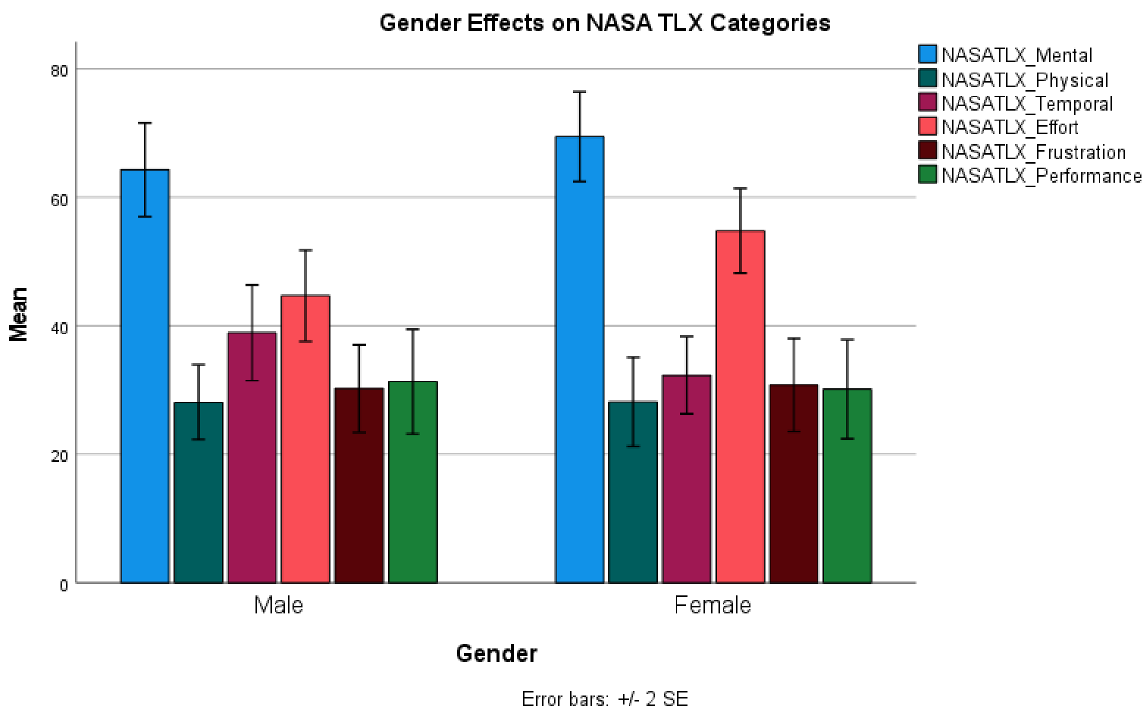


Figure 5-17: Gender Effects on NASA TLX Categories

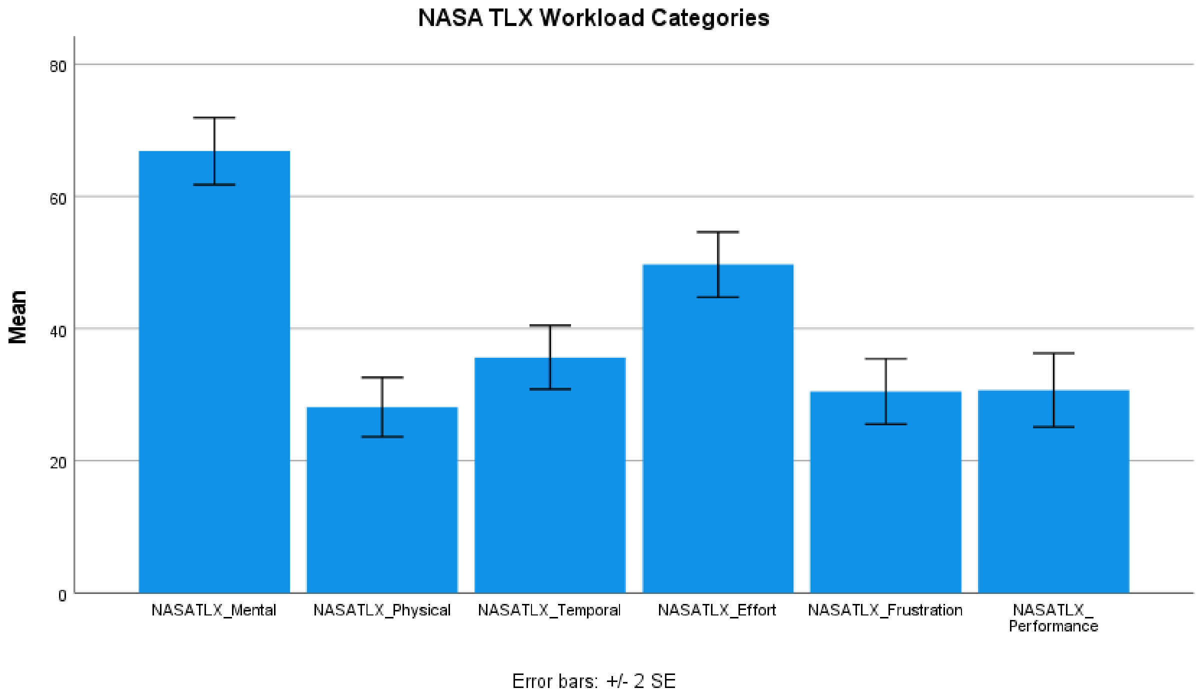


Figure 5-18: NASA TLX Workload Categories

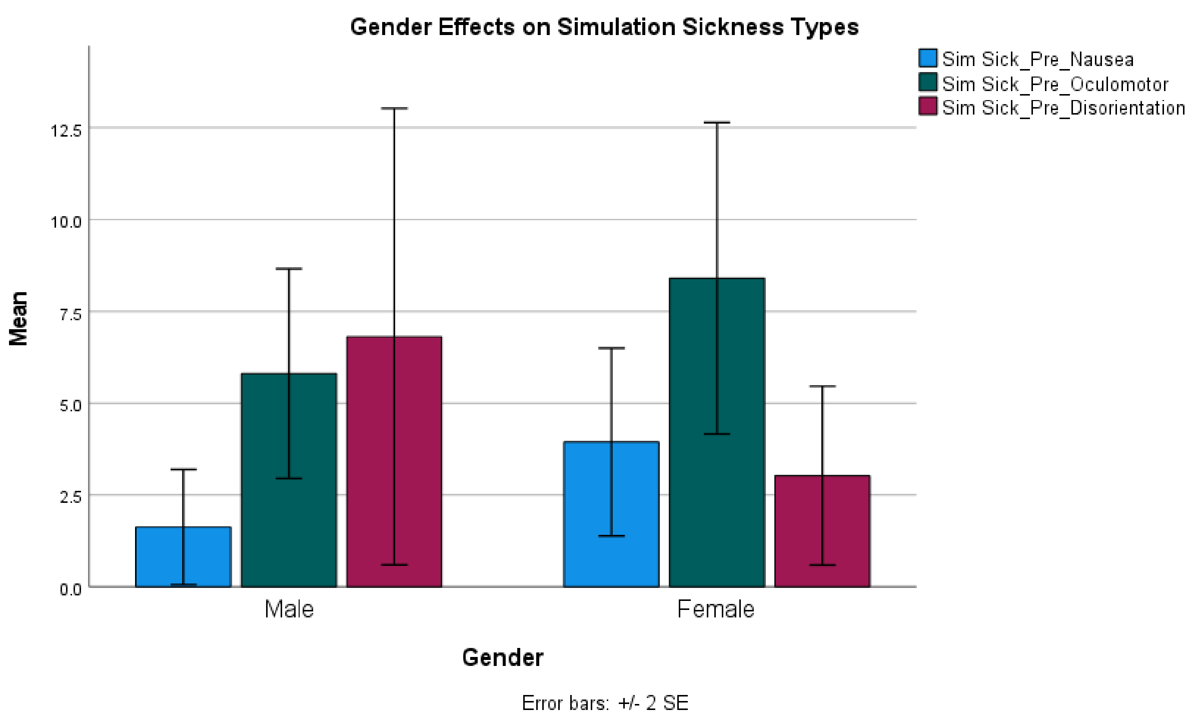


Figure 5-19: Gender Effects on Simulation Sickness Types

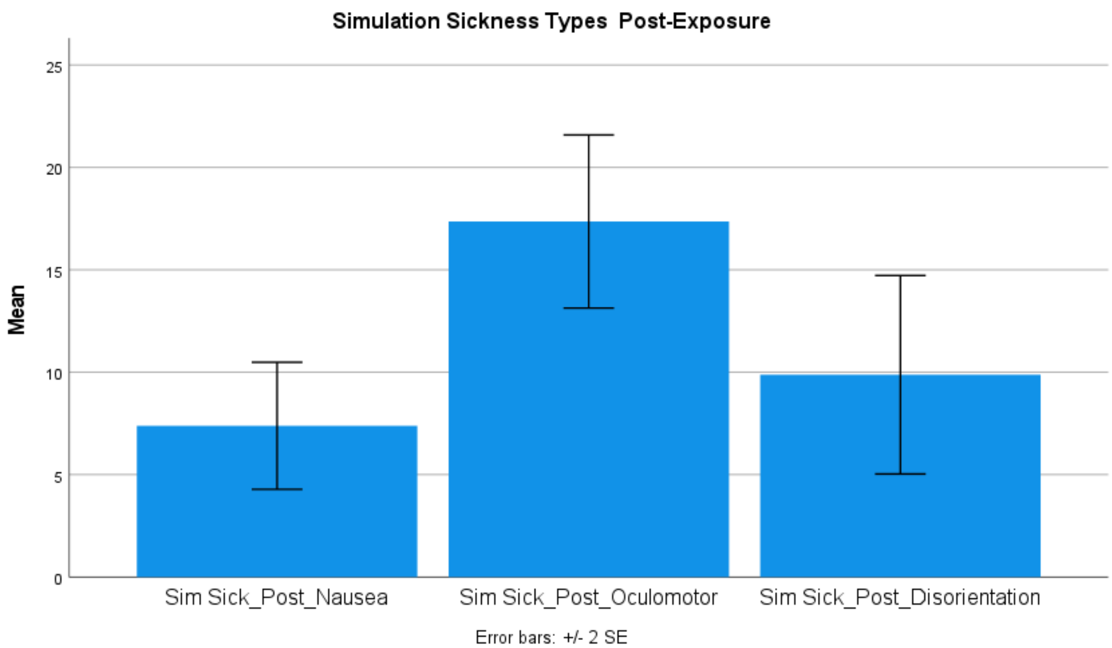


Figure 5-20: Simulation Sickness Types Post-Exposure

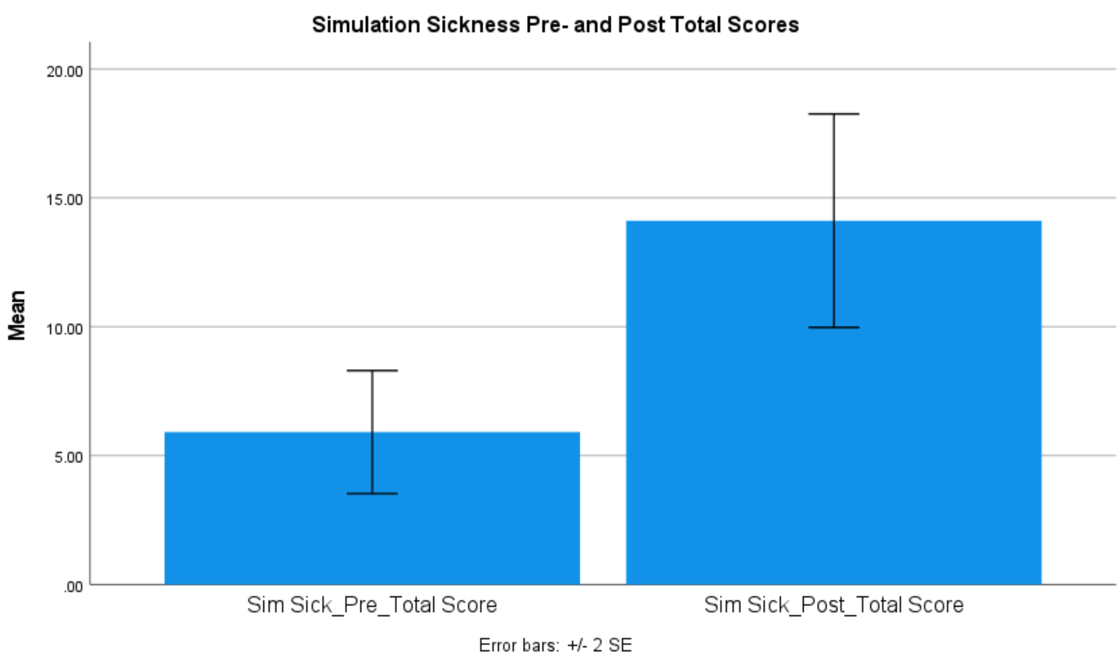


Figure 5-21: Simulation Sickness Types Pre- and Post-Exposure

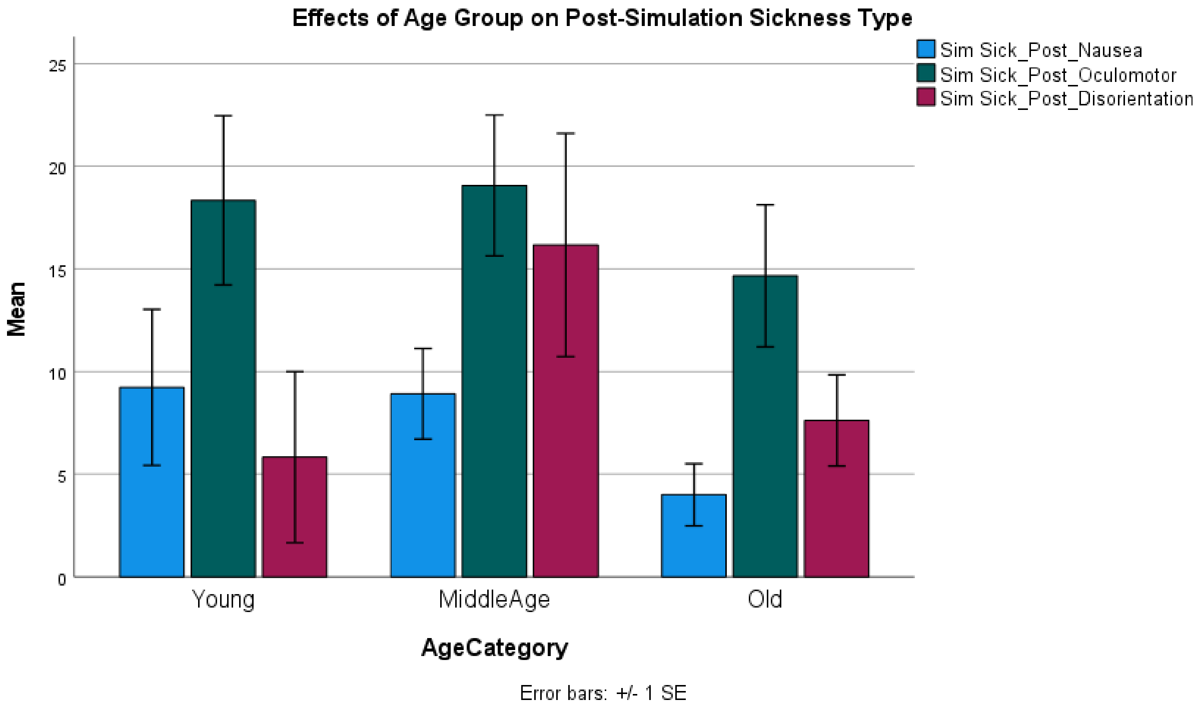


Figure 5-22: Effect of Age Group on Post-Simulation Sickness Types

5.7 Evaluation Models

A generalized regression model with Poisson distribution was used to examine the effect of all the parameters on driver behavior by block number as shown in **Table 5-13 and Figure 5-23** for Blocks 1-2 and **Table 5-14 and Figure 5-24** for Blocks 3-6, including message type (creative or traditional), message category (maneuvering, speeding, visibility, or work zone), Time of Day (day and night), traffic density (low and high), age (young, middle-age, and old) and with participant number as a random intercept and controlling for the number of words on the message. The results revealed that in Blocks 1-2, there was no significant difference in speeds between the message types or categories. However, the age, gender and traffic density had significant effect on speeds. On the other hand, when looking at Blocks 3-6, it was found that speeds were consistently lower in the creative messages' scenarios and across message categories compared to young males during daytime conditions. Another interesting finding revealed that when the number of words on the message increase, speeds decrease especially longer messages with 7-8 words. This can be attributed to the fact that effective communication messages to the driver with reasonable number of words increase the drivers' cognitive abilities and influence driver behavior in a positive manner.

Table 5-13: Regression Model with Poisson Distribution for Blocks 1-2

Model Summary	
Response	Longitudinal velocity
Distribution	Poisson
Estimation Method	Maximum Likelihood
Validation Method	None
Mean Model Link	Log

Measure	
Number of rows	1472
Sum of Frequencies	1472
-LogLikelihood	5471.4619
Number of Parameters	15
BIC	11052.339
AICc	10973.254
Generalized RSquare	0.6774655

Effect Tests

Source	Nparm	DF	Wald ChiSquare	Prob > ChiSquare
Traffic Density	1	1	204.25605	<.0001*
Gender	1	1	87.175884	<.0001*
Age	2	2	88.839658	<.0001*
Message Category	3	3	15.107598	0.0017*
Message Type	1	1	4.8175071	0.0282*
Word#	5	5	4.7815128	0.4431
TOD	1	1	0.002263	0.9621

Term	Estimate	Std Error	Wald Chi-square	Prob > Chi-square	Lower 95%	Upper 95%
Intercept	4.3911789	0.0219462	40035.328	<.0001*	4.3481651	4.4341927
Message Type [Creative-Traditional]	0.0228	0.0103878	4.8175071	0.0282*	0.0024403	0.0431597
Message Category [Maneuvering-Work Zone]	0.0220985	0.0093339	5.6052762	0.0179*	0.0038043	0.0403926
Message Category [Speeding-Work Zone]	0.0085291	0.018042	0.2234799	0.6364	-0.026832	0.0438907
Message Category [Visibility-Work Zone]	-0.028397	0.0148003	3.6813806	0.0550	-0.057405	0.0006108
TOD[Day-Night]	-0.000575	0.0120772	0.002263	0.9621	-0.024245	0.0230963
Traffic Density [Low-High]	0.1905874	0.0133354	204.25605	<.0001*	0.1644504	0.2167243
Age [Middle Age-Young]	-0.037322	0.0069076	29.192121	<.0001*	-0.050861	-0.023783

Term	Estimate	Std Error	Wald Chi-square	Prob > Chi-square	Lower 95%	Upper 95%
Age [Old-Young]	-0.06468	0.0069013	87.837829	<.0001*	-0.078206	-0.051154
Gender [Female-Male]	-0.052935	0.0056695	87.175884	<.0001*	-0.064047	-0.041823
Word# [3-8]	0.021069	0.0157489	1.7897267	0.1810	-0.009798	0.0519363
Word# [4-8]	-0.006096	0.0145074	0.1765761	0.6743	-0.03453	0.0223378
Word# [5-8]	-0.012223	0.0195088	0.3925706	0.5310	-0.05046	0.0260133
Word# [6-8]	-0.014707	0.0170283	0.7459393	0.3878	-0.048082	0.0186679
Word# [7-8]	-0.019055	0.0162262	1.3790983	0.2403	-0.050858	0.0127476

Table 5-14: Regression Model with Poisson Distribution for Blocks 3-6

Model Summary

Response	Longitudinal velocity
Distribution	Poisson
Estimation Method	Maximum Likelihood
Validation Method	None
Mean Model Link	Log

Measure	
Number of rows	1472
Sum of Frequencies	1472
-LogLikelihood	5555.7679
Number of Parameters	15
BIC	11220.952
AICc	11141.866
Generalized RSquare	0.7535008

Effect Tests

Source	Nparm	DF	Wald ChiSquare	Prob > ChiSquare
Traffic Density	1	1	398.6229	<.0001*
Message Category	3	3	177.77615	<.0001*
Gender	1	1	127.39074	<.0001*
Age	2	2	110.98993	<.0001*
Word#	5	5	54.472384	<.0001*
Message Type	1	1	32.658095	<.0001*
TOD	1	1	10.167247	0.0014*

Term	Estimate	Std Error	Wald Chi-square	Prob > Chi-square	Lower 95%	Upper 95%
Intercept	4.1614806	0.0225097	34178.871	<.0001*	4.1173625	4.2055987
Message Type [Creative-Traditional]	-0.062259	0.0108945	32.658095	<.0001*	-0.083612	-0.040906
Message Category [Maneuvering-Work Zone]	0.111821	0.0097984	130.23633	<.0001*	0.0926164	0.1310256
Message Category [Speeding-Work Zone]	0.1797017	0.0188609	90.777967	<.0001*	0.142735	0.2166683
Message Category [Visibility-Work Zone]	0.1560421	0.0152812	104.27229	<.0001*	0.1260915	0.1859927
TOD[Day-Night]	0.0397627	0.0124702	10.167247	0.0014*	0.0153215	0.064204
Traffic Density [Low-High]	0.2757989	0.0138137	398.6229	<.0001*	0.2487245	0.3028733
Age [Middle Age-Young]	-0.044839	0.007188	38.913034	<.0001*	-0.058927	-0.030751
Age [Old-Young]	-0.075056	0.0071871	109.05936	<.0001*	-0.089143	-0.06097
Gender [Female-Male]	-0.066669	0.0059069	127.39074	<.0001*	-0.078246	-0.055092
Word# [3-8]	-0.079422	0.0162407	23.9152	<.0001*	-0.111253	-0.047591
Word# [4-8]	-0.010324	0.0148886	0.4808104	0.4881	-0.039505	0.0188573
Word# [5-8]	0.0268243	0.0202383	1.7567587	0.1850	-0.012842	0.0664906
Word# [6-8]	0.0773129	0.0174473	19.635829	<.0001*	0.0431169	0.1115089
Word# [7-8]	0.0855198	0.0165971	26.550198	<.0001*	0.0529901	0.1180496

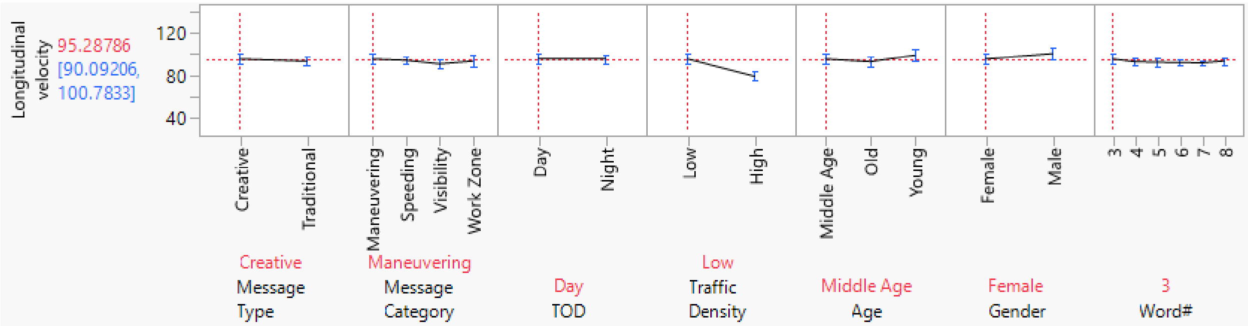


Figure 5-23: Profiler Results for Longitudinal Velocity for Blocks 1-2

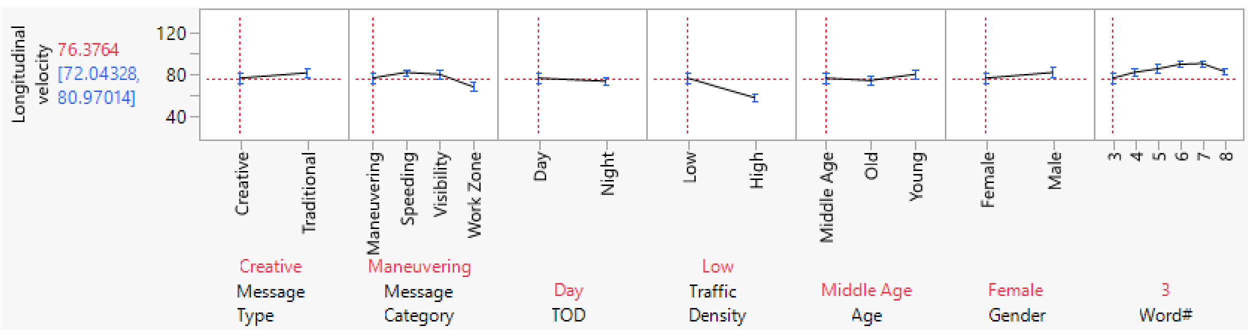


Figure 5-24: Regression model for Longitudinal Velocity for Blocks 3-6

5.8 Exit Surveys

Each participant was asked questions at the end of the study in an exit survey regarding the message types, and whether they noticed the signs or not and how many did they encounter. **Table 5-15** shows the questions that each person was asked in the survey regarding the messages and scenarios.

Table 5-15: Exit Survey Questions

Did you notice the dynamic message signs? (Y/N)	If yes, did you recall how many messages you encountered throughout the study?	Which message grabbed your attention the most?	Did your behavior change based on the message signs? Why?	Do you think the scenarios were logical and true to a real-life situation?

Table 5-16 shows the exit survey response data by the 92 participants. As can be seen, the messages were noticed by almost all the participants (90 out of 92). Almost half of them were able to recall the messages. 87% reported that the messages were able to change their behavior and 87% believed the scenarios were logical and represented real life situations. In addition, about 25% provided suggestions on how these messages changed their behavior such as paying more attention, reducing speed, fog messages, being more mindful of the conditions as well as the space between the other vehicles, acted as a reminder, becoming more attentive to what's coming ahead.

Table 5-16: Exit Survey Response Data

Group No.	Notice DMS		Recall Msg		Behavior Change		Do you think the scenarios were logical and true to a real-life situation?	
	Yes	No	Yes	No	Yes	No	Yes	No
Group-1	31	0	14	17	27	4	26	5
Group-2	28	2	14	17	31	0	29	2
Group-3	31	0	17	13	22	8	25	5
Total	**90**	**2**	**45**	**47**	**80**	**12**	**80**	**12**

5.8.1 Frequency Analysis

Of the 92 participants who noticed the DMS, a frequency analysis was done to see which DMS was the most noticeable. **Figure 5-25** shows a visual representation of the frequency analysis done for the messages. For a total of 92 participants, 80 mentioned that the signs affected their behavior in a positive manner. The most noticeable message was "Don't Hurry, Be Happy" as it reminded them of the happy song. Several participants thought the messages were funny. The complete exit survey results for the 92 participants are included in **Appendix H**.

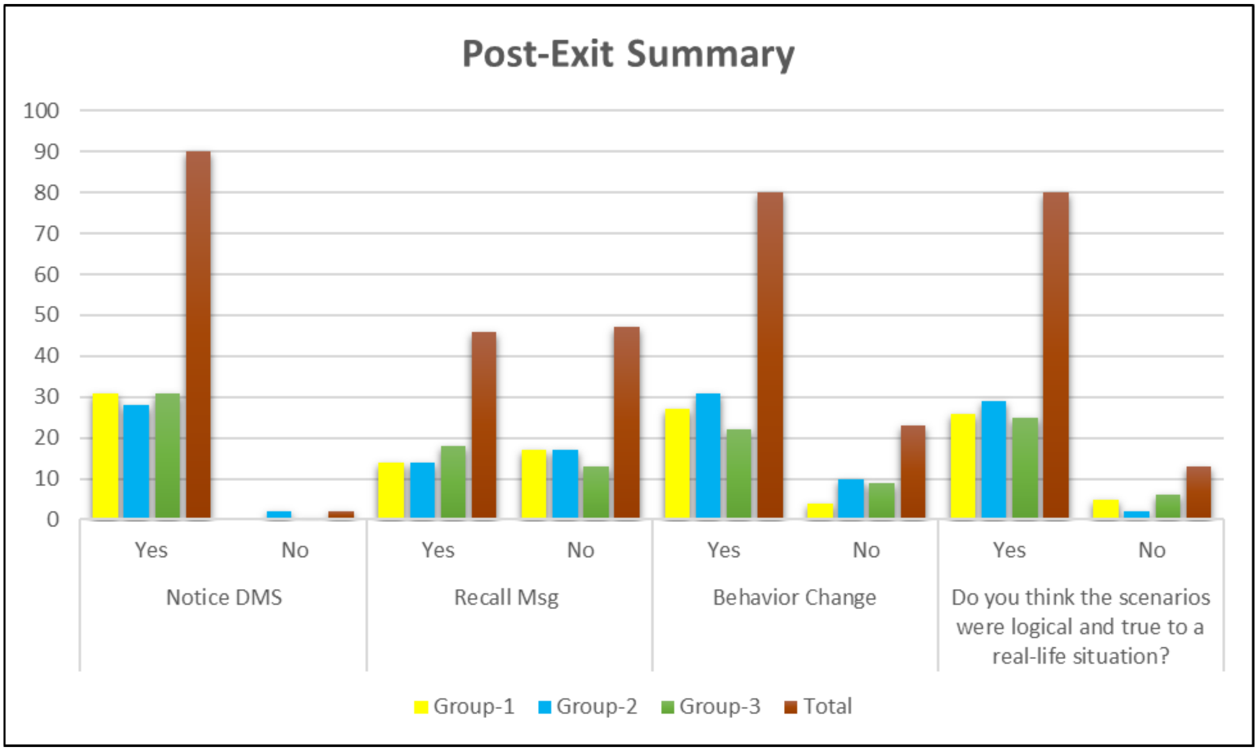


Figure 5-25: Exit Survey Responses

VI. CONCLUSIONS AND RECOMMENDATIONS

This research focused on analyzing the behavioral data extracted from the driving simulator, driver visual attention data extracted from the eye tracking device, and the participants' subjective responses to the surveys to understand the impacts of the creative messages on driver behavior. The different scenario parameters used in the experiment included message type, message category, time of day, traffic density, age and gender, time to notice, dwell time and number of fixations in order to develop an evaluation model inclusive of all the parameters. The evaluation model determined the optimal settings of all the significant parameters simultaneously to evaluate driver behavior in relation to driver performance.

The response variables entailed both bio-behavioral measures consisting of drivers' attention responses, driving performance accuracy, and eye movements. They were recorded in a series of simulated driving environments, where vehicle speed, deceleration, and lane-changing behavior were extracted from the driving simulator, while time to notice (TTN), legibility distance, perception-reaction time, and average gaze duration were identified from the eye-tracking device. In order to evaluate the effect of the studied parameters on the response variables and reduce the data set dimensionality, the analysis was broken down into six research questions. The data were extracted from the driving simulator and then aggregated over two main blocks: Blocks 1-2 and 3-6. Blocks 1-2 represented the aggregated data for the distance driven by the participants up until the DMS, while Blocks 3-6 represented the aggregated data for the distance driven after passing the DMS until the end of the scenario. It should be noted that the eye-tracking data was available from Blocks 1-2 only, while driving data were collected for both blocks.

Statistical analysis was conducted for 92 participants which had full data sets using mixed effects multiple regression models. Rather than using a basic linear regression model for all effects, linear mixed models (also called multilevel models) were used to account for both fixed and random effects. These models were useful in determining fixed effects when there are multiple observations (scenarios) per subject, including random effects to account for differences among group (of scenarios) means.

The analysis revealed that drivers tend to notice the traditional signs faster but look at creative signs longer. Further analysis demonstrated that the latter effect is due, in part, to specific message categories having more words per sign. Therefore, the purpose of the sign had a significant effect on driver's visual attention.

On the other hand, driver's visual attention toward road signs differed based on background characteristics, such as age and gender, with young women looking at creative signs longer compared to middle-aged men looking at traditional signs. Also, older participants took slightly longer to notice the road signs compared to younger participants. Thus, varying sign types may cater to different audiences.

A significant two-way interaction between message type and traffic density revealed that drivers noticed traditional signs in low-density traffic faster and looked at them for shorter durations, as compared to creative signs in high-density traffic. The two-way interaction between time-of-day and traffic density was also significant, with drivers noticing signs faster and looking for shorter durations during the night and low-density traffic.

The driver's time-to-collision was increased more in the presence of creative versus traditional signs which indicated safer conditions. Overall, creative signs lead to a greater increase in time-to-collision with reduced lane position shifts compared to traditional signs. It should be noted that the relative effectiveness of creative versus traditional signs depended, in part, on the sign category.

The main effect of age was statistically significant, with middle-age and older drivers having a greater time-to-collision than younger drivers. A main effect of gender indicated that female drivers had less changes in lane position following the road signs, as compared to male drivers. In addition, the significant interaction between sign type and age showed that older participants had reduced time-to-collision in the presence of traditional signs, as compared to young people viewing creative signs.

A significant main effect of time of day indicated that drivers had reduced time-to-collision and less changes in lane position during nighttime driving. In addition, the main effect of traffic density demonstrated that low-density traffic conditions resulted in less changes in lane position.

Moreover, the significant interaction between sign type, time of day and traffic density revealed that drivers had reduced time-to-collision and greater lane changes following traditional sign viewing in low-density nighttime driving, compared to creative sign viewing in high-density daytime driving.

The results revealed that in Blocks 1-2, there was no significant difference in speeds between the message types or categories. However, the age, gender and traffic density had significant effect on speeds. On the other hand, when looking at Blocks 3-6, it was found that speeds were consistently lower in the creative messages' scenarios and across message categories compared to young males during daytime conditions. Another interesting finding revealed that when the number of words on the message increase, speeds decrease especially longer messages with 6-8 words. This can be attributed to the fact that effective communication messages to the driver with reasonable number of words increase the drivers' cognitive abilities and influence driver behavior in a positive manner.

The exit survey response data by the 92 participants revealed that the messages were noticed by almost all the participants (90 out of 92). Almost half of them were able to recall the messages. 87% reported that the messages were able to change their behavior and 87% thought the scenarios were logical and represented real life situations. In addition, about 25% provided suggestions on how these messages changed their behavior such as paying more attention, reducing speed, fog messages, being more mindful of the conditions as well as the space between the other vehicles, acted as a reminder, and becoming more attentive to what's coming ahead. The results revealed that creative messages had a positive influence on driver behavior compared to the traditional messages in terms of reduced speeds, reduced acceleration, and increased time to collision with less lane position changes. Both the objective and subjective datasets were in agreement related to improved driving behavior, with participants' survey results matching the analysis of the objective performance factors. The results of this research will be used to update FDOT's safety message approval process and criteria (Topic Number 000-750-015).

APPENDIX

APPENDIX A: REVISED IRB APPROVAL AND AMENDMENT 1

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

APPROVAL

September 23, 2021

Dear Hatem Abou-Senna:

On 9/23/2021, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title:	Human Factors Study on the Use and Effectiveness of Innovative Safety Messages on Dynamic Message Signs
Investigator:	Hatem Abou-Senna
IRB ID:	STUDY00003292
Funding:	Name: FL Dept of Transportation (FDOT), Grant Office ID: 16207A25, Funding Source ID: BDV24 TWO 977-40
Grant ID:	16207A25;
IND, IDE, or HDE:	None
Documents Reviewed:	• Email to Participants , Category: Recruitment Materials; • Parking Map for Participants, Category: Recruitment Materials; • Questionnaires.pdf, Category: Survey / Questionnaire; • Revised Consent, Category: Consent Form; • Revised Flyer, Category: Recruitment Materials; • Revised Protocol, Category: IRB Protocol

The IRB approved the protocol from 9/23/2021.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. Guidance on submitting Modifications and a Continuing Review or Administrative Check-in are detailed in the manual. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Katie Kilgore
Designated Reviewer

Page 1 of 1

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

375-040-81
PROCUREMENT
OGC - 11/12

TASK WORK ORDER FOR MASTER UNIVERSITY AGREEMENT AMENDMENT

Master Agreement #: BDV24	Cost Center # - Task Work Order #: 977 - 40	Amendment #: 1
University: University of Central Florida		
Task Work Order Description: Human Factors Study on the Use and Effectiveness of Innovative Safety Messages on Dynamic Message Signs		

The effective date of this amendment is the date the Department signs the amendment, unless otherwise stated within the amendment.

Check all applicable terms

- [x] The time for completion of services for the subject task work order is extended thru 3/31/2023.
- [ ] The subject task work order is hereby canceled (no work has been performed and no payment is due).
- [ ] The total amount for services performed under this task work order is increased by $ ________________. The additional funds will be allocated as defined in the attached revised Exhibit B, Method of Compensation.
- [ ] The total amount for services performed under this task work order is decreased by $ ________________. The decrease in funds will be allocated as defined in the attached revised Exhibit B, Method of Compensation.
- [ ] There is no increase/decrease in the task work order amount. Funds are only redistributed between compensation elements as defined in the attached revised Exhibit B, Method of Compensation.
- [ ] The Scope of Service is hereby amended, attached hereto, and incorporated herein.
- [ ] Other:

Department Contact:

Name: Jennifer Clark Phone: (850) 414-4614

Office: Research Center Email: jennifer.clark@dot.state.fl.us

Departmental Approval:

J. Darryll Dockstader	Manager, Research Center		
(Name)	(Title)	(Signature)	(Date)

University Acceptance:

(Name)	(Title)	(Signature)	(Date)

Legal Review:

____

Master University Agreement Task Work Order Amendment Request

Contract-TWO # BDV24 – 977-40	Amendment # 1
Title: Human Factors Study on the Use and Effectiveness of Innovative Safety Messages on Dynamic Message Signs	
Start Date: 5/25/21	End Date: 10/31/2022
Project Manager: Dana Knox / John Easterling, P.E., PTOE	Principal Investigator: Hatem Abou-Senna, PhD., P.E.

Additional Time

Request for additional time for completion of services to 03/31/2023.

Justification: Recruitment efforts of participants were delayed due to COVID. These efforts have improved and been completed for the younger age group; however, additional time is needed to recruit participants from the oldest age group during the upcoming Fall semester. Currently, only two participants have been selected with 28 more needed in this age group.

Change to funding:

_____ increase project amount by $__________
_____ decrease project amount by $__________
_____ rebudget

Justification:

Attach a budget sheet for the request change.

Change in scope

Describe the change being requested:

Justification:

Attach a revised scope of service and a revised project schedule.

Other modifications:

_____ Change of principal investigator to ______________________________
_____ Change of title to ______________________________

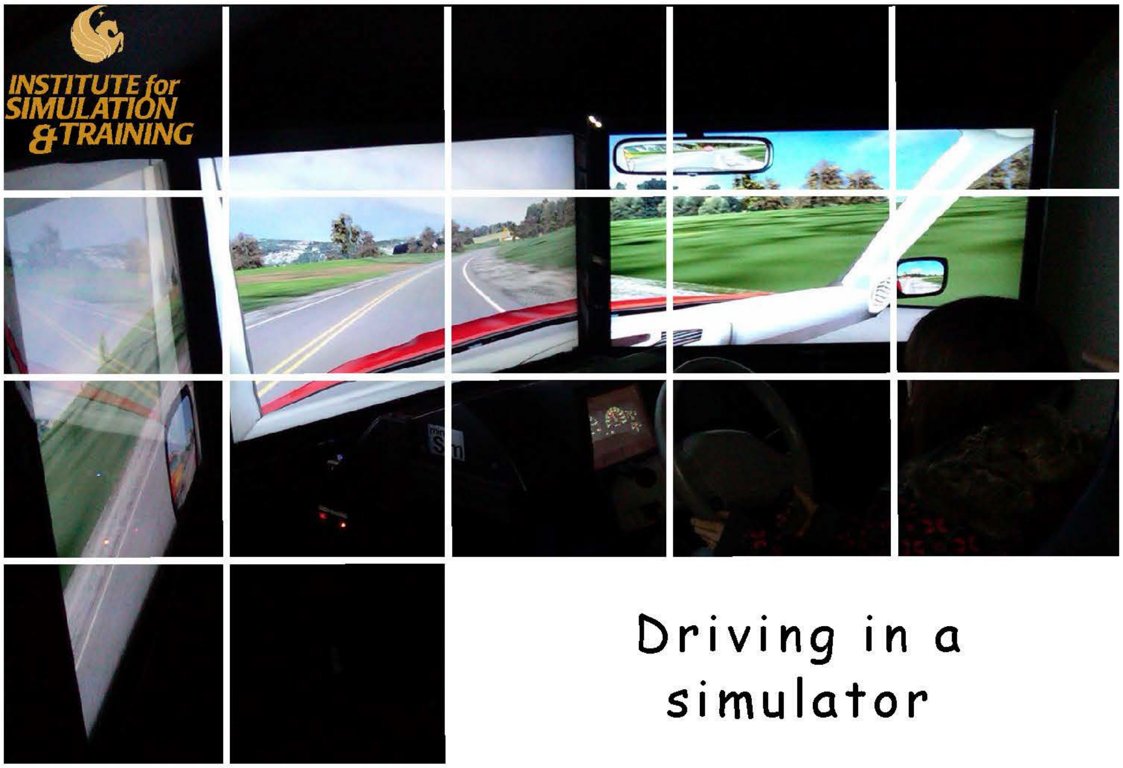
Requestor (provide contact information): Dana Knox - dana.knox@dot.state.fl.us

Note: Requests will not be processed without written FDOT project manager approval. Requested modifications must officially be processed as an amendment signed by the Research Center manager and the authorized party for the contractor in order to be reimbursable.

Revised Schedule

Deliverable # / Description as provided in the scope (included associated task #)	Anticipated Date of Deliverable Submittal (month/year)	TO BE COMPLETED BY RESEARCH CENTER (performance monitoring)
Project Kick off Meeting/Presentation	June/2021	
Task 1: Literature Review	July/2021	
Task 2: Design of Experiment and IRB Protocol/Approval	Oct/2021	**Approved in April**
Task 3: Human Factors Experiment	**Oct/2022**	
Task 4: Data Analysis and Develop Evaluation Model	**Jan/2023**	
Task 5.1: Draft Final Report	**Jan/2023**	
Task 5.2: Project Closeout Teleconference/Presentation	**Feb/2023**	
Task 6: Final Report	**Mar/2023**	

APPENDIX B: REVISED ADVERTISEMENT FLYER



Driving in a simulator

Bored of driving in the real world?

Try to drive in a virtual environment & earn $50!

You may be qualified to help in our transportation research study.

Only takes 2 hours of your time!

Requirements: You must have 20/40 normal or correction vision, and a valid driver's license. You cannot be vulnerable to motion sickness. Must be **35** or older, not pregnant, nor have any cognitive impairemnts.

Please contact the research assistants to schedule an appointment
Iman Sakalla: Iman.Sakalla@ucf.edu, or Jinchao Lin: Jinchao.Lin@ucf.edu

Location: Partnership II, Room 306H
University of Central Florida
3100 Technology Pkwy, Orlando, FL 32816

University of Central Florida

Principal Investigator: Dr. Hatem Abou-Senna, P.E.
This research study has been approved by UCF IRB.

Email for a person not signed up for the study:

Good morning/afternoon Participant,

The transportation engineering department needs your help with a study in exchange for a $50 gift card. We are conducting a study to help in improving the traffic control devices you encounter while driving on Central Florida highways. All you need to do is drive in our simulator for a few minutes through each of our scenarios. Participants must be adults 18 years old or older and have valid driver's license, not pregnant, nor have any cognitive impairments. The full study will require 2 hours of your time, and you will be compensated with a $50 gift card. We recommend that participants that need vision aids wear contact lenses rather than glasses as they work best with the eye tracking device. If you would like to sign up, please respond to this email with your available dates and times to conduct the study.

Regards,

Researcher's name

Reminder email for a person signed up for the study:

Good morning/afternoon Participant,

Just a friendly reminder that you are scheduled (weekday) (MM/YY) at XX: XX am/pm in the Institute for Simulation and Training Building to participate in the Driving in a Simulator Study. The address for UCF's Institute for Simulation and Training is 3100 Technology Pkwy, Orlando, FL 32826. Please park in the visitor parking lot on the southwest side of the building as shown in the map attached. **Otherwise, you will be towed**. We recommend that participants that need vision aids wear contact lenses rather than glasses as they work best with the eye tracking device.

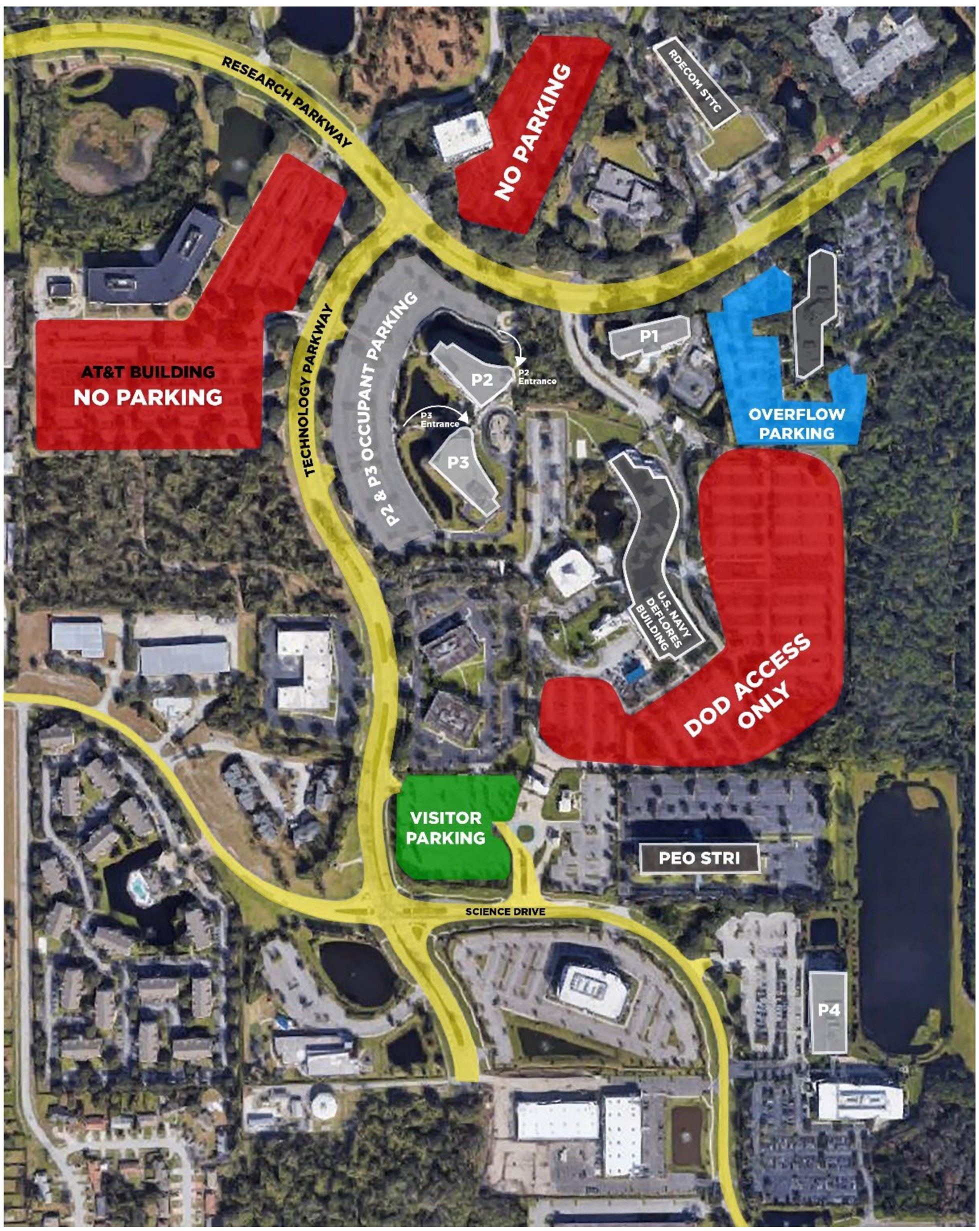
Regards,

Researcher's name

Partnership II & III Building
Visitor Parking Information

All visitors to the Partnership buildings may park in the "Visitor Parking" area located one block south of the buildings (indicated below in green). In the event there are no open spots available, visitors may park in the "Overflow Parking" area (indicated below in blue). Only occupants of PII and PIII are allowed to park in the parking lots adjacent to those buildings. **All others will be towed.**

PLEASE NOTE: *Parking along yellow curbs or in unmarked spots (aisles, fire zones, at corners, on grass, etc.) is prohibited in all parking areas and will be subject to towing. Parking across the street at AT&T is also prohibited, closely monitored, and subject to towing.*



APPENDIX C: PRE-TASK SURVEYS

1. How long have you had a Florida driver's license?
    a. Less than 5 years
    b. 5-10 years
    c. 11-15 years
    d. 16-20 years
    e. 21+
2. How old are you?
    a. 18-24
    b. 25-40
    c. 40-64
    d. 65+
3. How far do you typically drive in one year?
    a. 0-5000 miles
    b. 5,000-10,000 miles
    c. 10,000-15,000 miles
    d. 15,000-20,000 miles
    e. 20,000 miles+
4. What is your highest level of education?
    a. High school
    b. College
    c. Bachelor's Degree
    d. Graduate School
5. What is your range of income?
    a. 0-10,000
    b. 10,000-25000
    c. 25,000-40,000

   d. 40,000-55,000
   e. 55,000-70,000
   f. 70,000+

6. Have you been in any accidents that involved pedestrian(s) in the last 3 years?
   a. Yes
   b. No

If so, how many pedestrians were involved? Where did the crash occur (e.g., intersection, highway, freeway, mid-block, etc.)?

7. What vehicle do you normally drive?
   a. Sedan
   b. Pickup Truck or Van
   c. Motorcycle or Moped
   d. Professional Vehicle (Large Truck or Taxi)
   e. Other
8. Are you a professional driver, like taxi driver, truck driver?
   a. Yes
   b. No
9. Do you have a history of severe motion sickness or seizures?
   a. Yes
   b. No
10. Do you have an experience about virtual reality games (such as simulator)?
    a. Yes
    b. No

Driving Behavior Questionnaire

All responses recorded in this form are completely anonymous. None of your responses will be linked to any of your personal identifying information. Please respond as accurately and as honestly as you can.

(Adapted from Matthews et al., 1996)

* Required

1. **Please state your age in years** *

   ____

2. **Please state your gender** *

   ____

3. **Please state your race/ethnicity (Check as many boxes as appropriate)** *

   Check all that apply.

   - [ ] African-American / Black
   - [ ] Asian
   - [ ] Hispanic or Latino
   - [ ] Middle-Eastern
   - [ ] Native American
   - [ ] Pacific Islander
   - [ ] White
   - [ ] Other: ______________________________

4. **What is your class year?** *
   Mark only one oval.
   - Freshman
   - Sophomore
   - Junior
   - Senior
   - Other: ____________________

5. **Please state the year when you obtained your full driving license** *

   ____

6. **About how often do you drive nowadays?** *
   Mark only one oval.
   - Everyday
   - 2-3 days a week
   - About once a week
   - Less often

7. **Estimate roughly how many miles you personally drive each week** *
   Mark only one oval.
   - Less than 5 miles
   - 5-15 miles
   - 15-25 miles
   - 25-45 miles
   - Over 45 miles

8. **Do you drive to and from campus?** *

Mark only one oval.

- ◯ Everyday
- ◯ Most days
- ◯ Occasionally
- ◯ Never

9. **Please state which of these types of roads you use frequently (check one or more boxes as appropriate)** *

Check all that apply.

- ☐ Freeways
- ☐ Other main roads
- ☐ Urban roads
- ☐ Country roads

10. **During the last three years, how many minor 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 $800, or both).

____

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 $800, or both).

____

DSI

Office use only

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

Section A

1. Please state the year when you obtained your full driving license: ____

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

3. 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 ☐

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

5. Please state which of these types of road you use frequently (check one or more boxes as appropriate):
Freeways ☐ Other main roads ☐ Urban roads ☐ Country roads ☐

6. Have you ever fallen asleep at the wheel while driving?
Never ☐ Once or twice ☐ Three to five times ☐ More than five times ☐

7. Does your vehicle have a device that lets you know when you might be tired or sleepy?
Yes ☐ No ☐

If Yes, what is the name of the device?..

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 $1000).

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 $1000, 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 or drugs	Yes No	☐ ☐
(d) Other moving violation - please specify:	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, mark 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 would 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 0 1 2 3 4 5 6 7 8 9 10 not at all

2. I am disturbed by thoughts of having an accident or the car breaking down

very rarely 0 1 2 3 4 5 6 7 8 9 10 very often

3. Do you lose your temper when another driver does something silly?

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

4. Do you think you have enough experience and training to deal with risky situations on the road safely?

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

5. I find myself worrying about my mistakes and the things I do badly when driving

very rarely 0 1 2 3 4 5 6 7 8 9 10 very often

6. I would like to risk my life as a racing driver

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

7. My driving would be worse than usual in an unfamiliar rental car

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

8. I sometimes like to frighten myself a little while driving

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

9. I get a real thrill out of driving fast

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

10. I make a point of carefully checking every side road I pass for emerging vehicles

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

11. Driving brings out the worst in people

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

12. Do you think it is worthwhile taking risks on the road?

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

13. At times, I feel like I really dislike other drivers who cause problems for me

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

14. Advice on driving from a passenger is generally:

useful 0 1 2 3 4 5 6 7 8 9 10 unnecessary

15. I like to raise my adrenaline levels while driving

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

16. It's important to show other drivers that they can't take advantage of you

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

17. Do you feel confident in your ability to avoid an accident?

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

18. Do you usually make an effort to look for potential hazards when driving?

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

19. Other drivers are generally to blame for any difficulties I have on the road

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

20. I would enjoy driving a sports car on a road with no speed-limit

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

21. Do you find it difficult to control your temper when driving?

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

22. When driving on an unfamiliar road do you become more tense than usual?

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

23. I make a special effort to be alert even on roads I know well

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

24. I enjoy the sensation of accelerating rapidly

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

25. If I make a minor mistake when driving, I feel it's something I should be concerned about

very much 0 1 2 3 4 5 6 7 8 9 10 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 0 1 2 3 4 5 6 7 8 9 10 very much

27. I feel more anxious than usual when I have a passenger in the car

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

28. I become annoyed if another car follows very close behind mine for some distance

very much 0 1 2 3 4 5 6 7 8 9 10 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 0 1 2 3 4 5 6 7 8 9 10 very much

30. I try very hard to look out for hazards even when it's not strictly necessary

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

31. Are you usually patient during the rush hour?

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

32. When you pass another vehicle do you feel in command of the situation?

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

33. When you pass another vehicle do you feel tense or nervous?

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

34. Does it annoy you to drive behind a slow moving vehicle?

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

35. When you're in a hurry, other drivers usually get in your way

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

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

b) More drowsy or sleepy | 0 1 2 3 4 5 6 7 8 9 10 | No change

c) Maintain speed of reaction | 0 1 2 3 4 5 6 7 8 9 10 | Reactions to other traffic increasingly slow

d) Maintain attention to road-signs | 0 1 2 3 4 5 6 7 8 9 10 | Become increasingly inattentive to road-signs

e) Normal vision | 0 1 2 3 4 5 6 7 8 9 10 | Your vision becomes less clear

f) Increasingly difficult to judge your speed | 0 1 2 3 4 5 6 7 8 9 10 | Normal judgement of speed

g) Interest in driving does not change | 0 1 2 3 4 5 6 7 8 9 10 | Increasingly bored and fed-up

h) Passing becomes increasingly risky and dangerous | 0 1 2 3 4 5 6 7 8 9 10 | No change

---

Office use only a) b) c) d) e) f) g) h)

☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐

Stanford Sleepiness Scale

Degree of Sleepiness	Scale Rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

DSSQ-3 STATE QUESTIONNAIRE

PRE-TASK QUESTIONNAIRE

<u>Instructions.</u> This questionnaire is concerned with your feelings and thoughts at the moment. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Please do not choose a reply just because it seems like the 'right thing to say'. Your answers will be kept entirely confidential. Also, be sure to answer according to how you feel **AT THE MOMENT**. Don't just put down how you usually feel. You should try and work quite quickly: there is no need to think very hard about the answers. The first answer you think of is usually the best.

Before you start, please provide some general information about yourself.

Age............. (years) Sex. M F (Circle one)
Occupation...
If student, state your course...................................
Date today..................... Time of day now..............

For each statement, circle an answer from 0 to 4, so as to indicate how accurately it describes your feelings **AT THE MOMENT**.

Definitely false = 0, Somewhat false = 1,
Neither true nor false = 2, Somewhat true = 3, Definitely true = 4

1. I feel concerned about the impression I am making.		0	1	2	3	4
2. I feel relaxed.		0	1	2	3	4
3. The content of the task will be dull.		0	1	2	3	4
4. I am thinking about how other people might judge my performance.	0	1	2	3	4	
5. I am determined to succeed on the task.		0	1	2	3	4
6. I feel tense.		0	1	2	3	4
7. I am worried about what other people think of me.		0	1	2	3	4
8. I am thinking about how I would feel if I were told how I performed	0	1	2	3	4	
9. Generally, I feel in control of things.		0	1	2	3	4
10. I am reflecting about myself.		0	1	2	3	4
11. My attention will be directed towards the task.		0	1	2	3	4
12. I am thinking deeply about myself.		0	1	2	3	4
13. I feel energetic.		0	1	2	3	4
14. I am thinking about things that happened to me in the past		0	1	2	3	4
15. I am thinking about how other people might perform on this task	0	1	2	3	4	
16. I am thinking about something that happened earlier today.		0	1	2	3	4
17. I expect that the task will be too difficult for me.		0	1	2	3	4
18. I will find it hard to keep my concentration on the task.		0	1	2	3	4
19. I am thinking about personal concerns and interests.		0	1	2	3	4
20. I feel confident about my performance.		0	1	2	3	4
21. I am examining my motives.		0	1	2	3	4
22. I can handle any difficulties I may encounter		0	1	2	3	4
23. I am thinking about how I have dealt with similar tasks in the past	0	1	2	3	4	
24. I am reflecting on my reasons for doing the task		0	1	2	3	4
25. I am motivated to try hard at the task.		0	1	2	3	4
26. I am thinking about things important to me.		0	1	2	3	4
27. I feel uneasy.		0	1	2	3	4
28. I feel tired.		0	1	2	3	4
29. I feel that I cannot deal with the situation effectively.		0	1	2	3	4
30. I feel bored.		0	1	2	3	4

APPENDIX D: SIMULATOR SICKNESS QUESTIONNAIRE

Simulator Sickness Questionnaire (SSQ)

Developed by Robert S. Kennedy & colleagues under various projects. For additional information contact:
Robert S. Kennedy, RSK Assessments, Inc., 1040 Woodcock Road, Suite 227, Orlando, FL 32803 (407) 894-5090

Subject Number: ________ Date: ____________

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 <u>all</u> 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.

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

* 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.

POST 00 Minutes Exposure Symptom Checklist

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

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

* 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 E: POST-TASK QUESTIONNAIRES

DSSQ-3 STATE QUESTIONNAIRE

POST-TASK QUESTIONNAIRE

Instructions. This questionnaire is concerned with your feelings and thoughts while you were performing the task. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Please do not choose a reply just because it seems like the 'right thing to say'. Your answers will be kept entirely confidential. Also, be sure to answer according to how you felt **WHILE PERFORMING THE TASK**. Don't just put down how you usually feel. You should try and work quite quickly: there is no need to think very hard about the answers. The first answer you think of is usually the best.

For each statement, circle an answer from 0 to 4, so as to indicate how accurately it describes your feelings **WHILE PERFORMING THE TASK**.

Definitely false = 0, Somewhat false = 1,
Neither true nor false = 2, Somewhat true = 3, Definitely true = 4

1. I felt concerned about the impression I am making.	0	1	2	3	4
2. I felt relaxed.	0	1	2	3	4
3. The content of the task was dull.	0	1	2	3	4
4. I thought about how other people might judge my performance	0	1	2	3	4
5. I was determined to succeed on the task.	0	1	2	3	4
6. I felt tense.	0	1	2	3	4
7. I was worried about what other people think of me.	0	1	2	3	4
8. I thought about how I would felt if I were told how I performed	0	1	2	3	4
9. Generally, I felt in control of things.	0	1	2	3	4
10. I reflected about myself.	0	1	2	3	4
11. My attention was directed towards the task.	0	1	2	3	4
12. I thought deeply about myself.	0	1	2	3	4
13. I felt energetic.	0	1	2	3	4
14. I thought about things that happened to me in the past	0	1	2	3	4
15. I thought about how other people might perform on this task	0	1	2	3	4
16. I thought about something that happened earlier today.	0	1	2	3	4
17. I found the task was too difficult for me.	0	1	2	3	4
18. I found it hard to keep my concentration on the task.	0	1	2	3	4
19. I thought about personal concerns and interests.	0	1	2	3	4
20. I felt confident about my performance.	0	1	2	3	4
21. I examined my motives.	0	1	2	3	4
22. I felt like I could handle any difficulties I encountered	0	1	2	3	4
23. I thought about how I have dealt with similar tasks in the past	0	1	2	3	4
24. I reflected on my reasons for doing the task	0	1	2	3	4
25. I was motivated to try hard at the task.	0	1	2	3	4
26. I thought about things important to me.	0	1	2	3	4
27. I felt uneasy.	0	1	2	3	4
28. I felt tired.	0	1	2	3	4
29. I felt that I could not deal with the situation effectively.	0	1	2	3	4
30. I felt bored.	0	1	2	3	4

31. Please rate the MENTAL DEMAND of the task: How much mental and perceptual activity was required?

Low	0	1	2	3	4	5	6	7	8	9	10	High

32. Please rate the PHYSICAL DEMAND of the task: How much physical activity was required?

Low	0	1	2	3	4	5	6	7	8	9	10	High

33. Please rate the TEMPORAL DEMAND of the task: How much time pressure did you feel due to the pace at which the task elements occurred?

Low	0	1	2	3	4	5	6	7	8	9	10	High

34. Please rate your PERFORMANCE: How successful do you think you were in accomplishing the goals of the task?

Low	0	1	2	3	4	5	6	7	8	9	10	High

35. Please rate your EFFORT: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low	0	1	2	3	4	5	6	7	8	9	10	High

36. Please rate your FRUSTRATION: How discouraged, irritated, stressed and annoyed did you feel during the task?

Low	0	1	2	3	4	5	6	7	8	9	10	High

Participant: ____________________ **Task:** _____________ **Date:** ____________

NASA-TLX Questionnaire

Please rate your overall impression of demands imposed on you during the exercise using the following 100-point scale:

LOW |----------|----------|----------|----------|----------|----------|----------|----------|----------|----------| HIGH
0 10 20 30 40 50 60 70 80 90 100

1. **Mental Demand**: How much mental and perceptual activity was required (e.g., thinking, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Mental Demand rating (whole number between 0 and 100 inclusive): _____________

2. **Physical Demand**: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Physical Demand rating (whole number between 0 and 100 inclusive): _____________

3. **Temporal Demand**: How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Temporal Demand rating (whole number between 0 and 100 inclusive): _____________

4. **Level of Effort**: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Effort rating (whole number between 0 and 100 inclusive): _____________

5. **Level of Frustration**: How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Frustration rating (whole number between 0 and 100 inclusive): _____________

6. **Performance**: 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 in accomplishing these goals?

POOR |----------|----------|----------|----------|----------|----------|----------|----------|----------|----------| GOOD
0 10 20 30 40 50 60 70 80 90 100

Performance rating (whole number between 0 and 100 inclusive): _____________

APPENDIX F: EXIT SURVEY

1. Did you notice the dynamic message signs?

   a. Yes b. No

2. Did you recall how many messages you encountered throughout the study?

   a. Yes b. No

   If yes, how many messages did you encounter?

   ____

3. Which message grabbed your attention the most?

   ____

4. Why?

   ____

5. Did your behavior change based on the message signs?

   a. Yes b. No

   If yes, how did your behavior change?

   ____

6. Do you think the scenarios were logical and true to a real-life situation?

   a. Yes b. No

   If no, how could the scenarios be improved to simulate real life more?

   ____

APPENDIX G: DMS SCENARIO MESSAGES

Work Zone Signs

(a) Traditional Message – Daytime

(b) Traditional Message – Nighttime

Work Zone Signs

(c) Creative Message – Daytime

(d) Creative Message – Nighttime

Maneuvering Signs

(a) Traditional Message - Daytime

(b) Traditional Message - Nighttime

Maneuvering Signs

(c) Creative Message – Daytime

(d) Creative Message – Nighttime

Speeding Signs

(a) Traditional Message – Daytime

(b) Traditional Message – Nighttime

Speeding Signs

(c) Creative Message – Daytime

(d) Creative Message – Nighttime

Visibility Signs

(a) Traditional Message – Daytime

(b) Traditional Message – Nighttime

Visibility Signs

(c) Creative Message – Daytime

(d) Creative Message – Nighttime

APPENDIX H: EXIT SURVEY RESULTS

Group-1

Participant Number	DMS Attention	Why Attention	Behavior Change		Action	Do these scenarios feel real?		Suggestion
			Yes	No		Yes	No	
1001	workers ahead give them a break		√		slowed down	√		N/A
1002	right lane closed ahead	it was the most repetitive	√		If there was some traffic message, it was logical to slow down	√		N/A
1003	speeding enforced	ticket able offence	√		Follow rules	√		N/A
1004	speeding enforced	ticket able offence	√		N/A	√		N/A
1005	it is not a race	to slow down	√		concentrate more	√		N/A
1006	warp speed is for space travel	random movie reference	√		I focused more on the tasks mentioned. For the ones that said to not tailgate I consciously put more distance between myself and other cars		X	Kind of. No side view mirrors. Rear-end collision seemed more imminent than real life

1007	It's called a turn signal, Use it	seemed kind of sassy	√		if it said use your signal, I used it in that moment and turned just because		X	I saw a man materialize out of thin air
1008	All of them	Because they all were necessary	√		N/A	√		N/A
1009	Fog ahead reduced visibility	The message indicated to me that there would be quite a hazardous situation up ahead.	√		For some of the messages I become more attentive towards what was ahead.	√		N/A
1010	the one about warp speed	seemed like an odd place for a joke	√		when it said fog ahead, I reduced speed	√		N/A
1011	It's called a turn signal use it	Most people on the road do not use their turning signals		X	N/A	√		N/A
1012	visibility low, drive slowly	it rhymed so it was easy to remember	√		I slowed down and watched the cars around me more carefully	√		N/A
1013	It’s not a race	I'm unsure, it’s just the first sign that came to my	√		It slightly lightened my mood. Some of the signs were	√		N/A

		head. It seems most like something I would see on a highway.			funny			
1014	watch the speed limit	majority of the time the speed limit was 70, but at night the speed limit would change to 60 if you weren’t paying attention	√		I paid more attention to not tailgating the car ahead of me	√		N/A
1015	something with speeding	because I was speeding	√		slowing down	√		N/A
1016	Don't hurry be happy	Bad pun		X	N/A	√		N/A
1017	workers ahead give them a break	it was more recent	√		I payed more attention to following the rules they laid out	√		N/A
1018	Slow down	the messages were funny	√		because it reminded you	√		N/A
1019	the ones dealing with a situation I needed to look out for (fog,	Knowing these things would affect how I approached the rest of the	√		was more focused/aware, drove slower/more carefully	√	X	have more people driving below the speed limit in the passing lane

	construction, etc.)	drive						
1020	low visibility because of fog	it made me slow down so I could focus better on potential traffic.	√		slowed speed	√		N/A
1021	Do not hurry be happy	Cute message	√		Tried to drive better and within rules of the road	√		More dynamic behavior of other drivers and more realistic weather
1022	Warp Speed is only for spaceships or something like that	It made me silently chuckle		X	N/A	√		N/A
1023	Speeding is enforced	much more aggressive than other signs, the difference stood out		X	N/A	√		N/A
1024	don't hurry be happy	play on words	√		slowed down, switched lanes	√		N/A
1025	The message that compared speeding to space travel.	I thought it was funny.	√		If the sign sounded aggressive, I was surprised and if it was funny then I was happy.	√		N/A

1026	Don't hurry, Be happy	Was short	√		Felt like I needed to follow the rules of driving more	√	X	The speedometer was different than most sedans and the RPGs shifted slow, got into the 4000s sometimes
1027	Don’t hurry, be happy	It’s a play on words from don’t worry	√		Helped me relax more.	√		N/A
1028	Don’t hurry, be happy	It was short and sweet and realistic to what i would see in real life	√		I would be more mindful of the conditions as well as the space between the other cars and i	√		N/A
1029	Hyper speed is for space	It was Whitty	√		Slowed down, changed lanes	√		N/A
1030	It’s not a race!	sounds wise	√		limiting the speed and change of lanes before construction site	√		N/A
1031	Workers Ahead	There were people on side of road.	√		I tried to be more careful of where I was going	√		N/A

Group-2

Participant Number	DMS Attention	Why Attention	Behavior Change		Action	Do these scenarios feel real?		Suggestion
			Yes	No		Yes	No	
2001	slow down	do not	√		I slow down	√		N/A
2002	roadwork	bright orange and easy to see		X	N/A	√		N/A
2003	do not hurry be happy	emotional	√		follow them.		X	N/A
2004	Fog	Warning about increased visibility while traveling at high speed among vehicles and alongside obstructions.	√		I slowed down and I changed lanes.	√		N/A
2005	wrap speed for aliens, slow down	funny and innovative	√		thought about the sign in a different way and tried to follow it	√		graphics could be better and simulated movements.
2006	warp speed	message was long, but funny		X	N/A	√		N/A
2007	Workers Ahead, Give Them a Break	somewhat funny	√		tried to comply with any instructions	√		N/A

2008	speeding	it was funny		X	N/A	√		If possible, they could have tactile feedback in the seat, horns, etc.
2009	Slow Down	Because I was concerned, I was speeding.	√		Anticipated a conflict on the road was coming. Adjusted accordingly.	√		show the vehicles coming up behind you in the lane next to you instead of just appearing
2010	All	They were bright		X	N/A	√		N/A
2011	The play on Don't Worry, Be Happy	The signs were often humorous and practical	√		It helped me be more aware of my 'surroundings'.	√		ANV
2012	warp speed	it was funny	√		I checked my speed	√		Rain as depicted was truly strange to see and distracting.
2013	Speed Limit Enforced	potential for speeding ticket	√		Slowed down	√		N/A
2014	ANV	ANV		X	ANV	√		N/A
2015	None	N/A		X	N/A		X	N/A
2016	one about not driving at warp speed	amusing	√		slowed down when road work was ahead and when low visibility ahead	√		N/A

2017	slow down fog	driving in fog is dangerous	√		slowed down, more attentive to traffic	√		N/A
2018	Speed signs	They were funny or cute	√		Made me more aware of what they wanted me to be aware of	√		N/A
2019	roadwork ahead	usually requires lane changes, reduced speed	√		alert to changes in road conditions	√		N/A
2020	Low Visibility	Potentially higher accident rate	√		Adapted to the sign message	√		N/A
2021	Road worker signs	to slow down and ensure the safety of workers	√		To observe and pay attention to all signs	√		N/A
2022	ALL	Important messages		X	N/A	√		N/A
2023	workers on the road	human life involved	√		slowed down	√		N/A
2024	workers present give them a break	I don’t know	√		I hit the break	√		N/A
2025	watch for vehicle on the shoulder	expect vehicles from the side	√		slow down or be more carful in working area	√		N/A

2026	Speed limit enforced	I don't want the cops to stop me	√		slowed down	√		N/A
2027	Drive with caution	To avoid any accidental situations		X	N/A	√		N/A
2028	Low visibility	light was not working	√		more careful	√		N/A
2029	Do not worry be Happy	it was positive	√		slowed down	√		N/A
2030	do not tailgate	easy to read		X	N/A	√		N/A
2031	do not hurry be happy	it is funny		X	N/A	√		N/A

Group-3

Participant Number	DMS Attention	Why Attention	Behavior Change		Action	Do these scenarios feel real?		Suggestion
			Yes	No		Yes	No	
3001	Construction workers	safety of workers	√		Pay more attention to the surroundings		X	Rain was unrealistic and could not tell if the headlights were on.
3002	warp speed	funny		X	N/A	√		N/A
3003	Slow Down	Good reminder for drivers		X	N/A	√		N/A
3004	one with reference to star trek	required most thought to associate with driving	√		reminder to turn on headlights during rain	√		Needed some practice to get feel for brakes
3005	Warnings	Prepared for hazards ahead	√		I heeded the warnings	√		I am not sure the lighting shown by the headlights was accurate or that the rearview mirror was as accurate as it could be

3006	workers present	potential risk of worker injury	√		slowed down, increased field of vision, checked lights	√		
3007	workers	people at risk	√		slowed, put on blinkers		X	controls on the car are not like a real vehicle
3008	not a race	just because		X	N/A	√		N/A
3009	Don't worry, be happy	unexpected		X	N/A	√		N/A
3010	Be Happy	Different		X	N/A	√		N/A
3011	don't worry be happy	catchy tune	√		watched for situation to develop		X	I drove more slowly than my actual pace on the road
3012	slow down construction ahead	lives are at stake	√		hyper aware of surroundings	√		N/A
3013	Don't Hurry. Be Happy.	Made me feel good.	√		Slowed down. Moved over.	√		Get crazy drivers out of the program.
3014	no tailgating	people drive fast without enough room to stop in an emergency	√		became more cautious	√		N/A
3015	lane closed	required change of lane	√		change of lane		X	cars behind would brake

3016	workers	did not want to hit one	√		more alert	√		N/A
3017	N/A	N/A	√		more alert to the subject of the message	√		N/A
3018	N/A	N/A	√		slowed down in working zone	√		N/A
3019	slow down	good advice	√		cause down to slow down	√		N/A
3020	construction warning	i felt it was an important message	√		slowed down	√		N/A
3021	Don’t hurry be happy	clever	√		more attention ahead	√		N/A
3022	Don't worry, be happy ;0)	It made me smile		X	N/A	√		N/A
3023	fog alert	i hate driving in fog	√		slowed down		X	not much traffic from behind
3024	don't hurry	humorous		X	N/A	√		N/A
3025	turn signal suggestion	many individuals seem to need constant reminding		X	N/A	√		N/A
3026	workers ahead	I was required to do something	√		Became more alert	√		N/A

3027	speed limit	legal consequences	√		slow down, change lane	√		N/A
3028	men working	required changing lanes	√		changed lanes	√		N/A
3029	N/A	N/A	√		N/A	√		Improve graphics and physical simulator to be more like a real car.
3030	construction, headlight usage	Indicates conditions will possibly be changing	√		Additional concentrations		X	better side view and rear view mirrors, warning to check headlight function
3031	tail gate	hard not to do in simulation		X	N/A	√		N/A